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ENGINEERING:

An Illustrated Weekly Journal.

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Particulars of the proposed amendment were set forth in the *Illustrated Official Journal (Patents)*, issued on the 30th December, 1916.
Any person, or persons, may give notice of Opposition to the Amendment by leaving Patents Form No. 18 at the Patent Office, 25, Southampton Buildings, London, W.C., within one calendar month from the date of the said Journal.
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Russian Engineer (British University), drawing-office and shop experience, energetic, thorough commercial grasp. Desires to Represent or Travel in Russia for reliable British Firm.—Address, F 896, Offices of ENGINEERING.

Tin Stamping Wanted.—Tin Stamping Presses (19 and 20 power), in partial use, are at liberty for Additional Work. Aeroplane or small munition parts preferred.—Address, in first instance, F 874, Offices of ENGINEERING.

Contractors Able to Supply early, with Services of Skilled Erector, Five Electric Travelling Cranes—Three 52 ft. span, Two 36 ft. span, approximately, for one ton, are REQUESTED to COMMUNICATE with Mr. HUBERT BAINES, Deputy Chief Engineer, H.M. Office of Works, Storey's Gate, Westminster, London, S.W. Priority P2 will be given. F 894

Wanted, a Second-hand ELECTRIC GENERATING SET, about 200/250 kilowats capacity, with 240 volts direct current shunt dynamo, direct coupled to high speed compound engine; suitable for 120 lbs. steam pressure; Bellis or Browett engine preferred.—JOSEPH SANKEY and SONS, Ltd., Hadleigh Castle Works, Wellington, Salop. F 876

Wanted, Good Second-hand PLATE BENDING ROLLS, capable of bending to at least two-thirds of a circle 27 inches inside diameter, and dealing with plates 10 ft. wide, 1 in. thick cold, 2 in. thick hot.
Full particulars and where can be inspected to J. SAMUEL WHITE & CO., Ltd., East Cowes. F 889

Required, for Urgent War Work under Class "A," 400 ft. 6 × 3 H.S. JOISTS, in long spans.—Address, F 860, Offices of ENGINEERING.

Locomotive.—Wanted, One or two good Second-hand SHUNTING ENGINES, standard gauge, cylinders about 12 by 18, preferably six-wheel, coupled, and must insure at not less than 120 lbs.—WORKS ENGINEERS, AUSTIN MOTOR COMPANY, Ltd., Northfield. F 900

Wanted, One Triple Expan- SION HIGH-SPEED ENGINE, 500 H.P., forced lubrication. State where to be seen and lowest price. Bellis Morcom type preferred.—Address, F 905, Offices of ENGINEERING.

WELDING GLASS IN OPTICAL CONTACT.

FOR many optical researches glass cells are wanted, formed by two strictly parallel walls or windows, and different pieces of glass, lenses and prisms, &c., have frequently to be combined in such a way as to keep the surfaces optically true. Glass surfaces can be polished without difficulty to be so nearly plane or so nearly of the same curvature that they show less than one interference fringe per inch when placed together and examined by light reflected from the interfaces. Those surfaces may be brought into optical contact so that the two pieces of glass act optically as if they were one block by applying a pressure of several pounds per square inch. The hypothenuse of a prism of 45 deg. may, for instance, be united to the face of another piece of glass without introducing any reflection from the common interface.

Unions so made can easily be separated again by several means however, by sudden heating or cooling of the piece, by a force applied in a shearing direction, or by the application of liquids which gradually creep in between the surfaces. A cell constructed of plates of glass in optical contact with a separating piece of U shape could be made very accurately parallel; but the surfaces could be too easily separated again. Various cements like Canada balsam are, of course, largely used in optical combinations. But it is difficult by their aid to ensure parallelism within one minute of arc, and if the walls of the cell form a wedge of an angle only of a few seconds, instead of a cavity with plane-parallel walls, interference work may be seriously impaired.

The adhesive material may, moreover, require baking to harden completely; it may be attacked by the liquid within the cell, especially if organic, or it may strain the materials which it holds together and affect the optical uniformity of the parts. If pieces of glass could be welded without affecting the optical truth of their surfaces, considerable advantages would be gained. Attempts to effect such optical junctions by heating have been unsuccessful so far, though bifocal lenses are made by uniting two lenses, either by cementing or by fusing; in the latter case, however, the flint is really fused, and optically true contact is not aimed at. But Messrs. G. R. Parker, B.Sc., and A. J. Dalladay were able on Monday the 18th ult., at the meeting of the Faraday Society, to describe some successful experiments they have been conducting, under the guidance of Mr. F. Twyman, in the research laboratories of Messrs. Adam Hilger, Limited, and to exhibit some excellent specimens of optical welding.

The secret of the success lies, as might be expected, in the selection of the proper temperatures and pressures. It was essential, Mr. Dalladay, who is now in charge of this investigation, pointed out, that the temperature at which the union took place should be not only far below the melting-point of the glasses to be joined, but also below the annealing temperature; for even at that latter temperature very slight strain would cause deformation of worked glass surfaces. When heated gradually glass becomes less and less viscous, until it is finally melted; the viscosity remains too pronounced, however, for the distinction of a definite melting-point, which might be somewhere between 1,100 and 1,400 deg. C. Much below that melting-point, on the other hand, glass was found to be sufficiently plastic to deform gradually under stress; the strain would betray itself under examination by the polarised beam.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

When a piece of glass with two plane-parallel surfaces was being gradually heated in an electric furnace, which admitted of examination by transmitted polarised light, the strain caused by the unequal heating of different parts of the specimen would be quite distinct at low temperatures, but would suddenly disappear at a certain temperature long before the melting-point was reached. At that temperature the glass was sufficiently mobile to accommodate itself rapidly to stresses, and this temperature was the annealing-point at which a badly annealed piece of glass would lose internal stresses and remain perfectly annealed if cooled at a sufficiently slow rate.

At the annealing temperature the glass still possessed considerable viscosity; but it would yield to a tool, and two pieces pressed together would not remain optically true. The mobility of the glass was found by Messrs. Parker and Dalladay to follow the exponential law $S_T = S_{T_1} A^{\frac{T - T_1}{N}}$, in which S indicated the mobility at the temperature T, and A and N were constants. For small $(T - T_1)$ the index $(T - T_1)/N$ would be small, equal to 1, 2, 3, &c. When, for example, $A = 2$ and $N = 8$, the values of the mobility ratio S_T / S_{T_1}, would be respectively $= 2^1$, $2^2 = 4$, $2^3 = 8$ for $T_1 = 552$, 544, 536 deg. C.; that is to say, glass would become twice as "soft" for a rise in temperature of 8 deg.

At 60 or 70 deg. C. below the annealing temperature the glass would be sufficiently hard to bear considerable local pressure for short periods. The experimenters had thus first to determine the annealing temperature, and to conduct their operations afterwards at 70 or even at 90 deg. C. below this temperature to be on the safe side. At 60 deg. below the annealing temperature they had found that two pieces of glass in optical contact would unite within less than an hour, and any slight external deformation produced by the compression could be remedied again by a few strokes of a polishing tool; the condition of the optical surfaces could thus be restored without difficulty.

Entering into experimental detail, Mr. Dalladay first demonstrated the methods of distinguishing between optical contact and complete union. That cementing might set up strain he proved by Fig. 1, illustrating the distortion of a glass plate, 1.25 in. across, 0.1 in. thick, cemented to a piece of brass tube; the interference pattern shown was produced by the interference between the plate—which had been very plane to start with, showing less than one interference ring across its entire face—and a proof plane of quartz, and it indicated that the centre of the plate had been depressed by about $\frac{1}{3000}$ in.; this distortion would render the plate unfit for accurate optical instruments. The two discs of glass illustrated in Fig. 2 were merely in optical contact, and the diamond crack through the upper glass had not spread into the lower glass. In Fig. 3, on the other hand, illustrating a corner broken from a cell welded by the new process (as will be explained), the fracture travelled without hindrance across the joint AA. The electric furnace in which the welding was effected was a tube, 14 in. long, oval in section ($3\frac{1}{2}$ by $2\frac{1}{4}$ in.), wound with platinum and fitted with double silica windows at the ends, to admit of watching the union by means of polarised light. The furnace temperature was controlled by means of two resistances, in series, for rough and for fine adjustment.

Fig. 4 illustrates the first, partly successful attempt at making a cell of hard crown glass for a Rayleigh interference refractometer. Three glass plates were united; the middle plate was 10 mm. in thickness and had been drilled in the way indicated; the two outer plates, each 3 mm. in thickness, served as windows. The cell was heated, without applying pressure to the three glasses, in the furnace to 460 deg. C., the temperature rising by 2 deg. per minute; after being kept at 460 deg. for 2 hours the cell was cooled at the rate of 4 or 5 deg. per minute. It was noticed that at about 200 deg. the plates were separating at the one corner, and that small blister-spots developed. The cooled plates were found partly in contact; that contact was sufficiently perfect to withstand sudden temperature changes and the action of water; a knife blade forced in between the middle plate and upper window broke off the one corner, but left the rest intact. The cell was then compressed in a vice for the purpose of applying a large shearing stress; the cell then appeared as illustrated, contact being perfect except at the arc marked X. The spots just mentioned proved to be due to minute black particles of carbonised cellulose from the rag used in cleaning the surface. These particles generated gas when heated; the expanding gas forced the plates apart and gave rise to Newton rings, and the spot appeared convex. When such a gas blister was near an edge, the gas was blown out and escaped, and the surfaces returned to complete contact. The arc X was instructive in another respect; it was due to the burr round the drilled edge. When a thin plane-parallel plate, Mr. Dalladay remarked, was finely ground on one side, it became a concave mirror of long focus on the other surface. Similarly the burr of the drill prevented complete optical contact, though its height was only a few wave-lengths;

the burr had been removed by polishing, but traces of it had evidently remained. There was, further, a faulty spot at Y—the X is at the internal face of the front window, the Y at the inside of the back window—where the fracture travelled round the burred edge, instead of passing right across it; this is better shown in Fig. 5, magnified 6 diameters. A second cell made proved almost perfect. It was of the same glass and pattern, and was made by heating the glasses up to 523 deg., at the rate of 1½ deg. per hour, keeping at 523 deg. for two hours, and cooling at the same rate as before, of 4 or 5 deg. per minute.

Pressure was in this second case applied by means of a hand-screw clamp, through two brass plates, ¼ in. in thickness, a few sheets of paper being interposed between the brass and the glass; this paper was carbonised, but the harm done was easily remedied by repolishing. Under severe mechanical stress this cell broke and showed a defect (compare Fig. 3, already referred to). In other parts the contact was perfect, and the block broke as a whole with conchoidal fracture. The optical surfaces had remained perfect as regards plastic deformation; the outer surfaces were slightly corroded by the paper ash. Examination by a Babinet compensator demonstrated that the maximum stress had amounted to 150 lb. per square inch; that amount, which was negligible for most purposes, could easily be decreased.

The third cell (illustrated in Fig. 6), of slightly different pattern, was also welded at 523 deg., *i.e.*, 90 deg. below the annealing-point. Here the parts in contact were all narrow, so that no spot was more than 2.5 mm. from some edge; the gas developed at any spot would thus have a chance to escape. The internal surfaces of the cell windows were found to be parallel within one second of arc, both before and after union. The heating had not impaired the parallelism, therefore, and by slow cooling all traces of strain could be avoided.

In the cases so far mentioned the glasses to be joined had been of the same kind. When glasses of different kinds had to be united, difficulties were introduced, Mr. Dalladay explained, by the different expansion coefficients, by the different annealing points of the glasses, and by the degree of ease with which they would fuse together. Owing to the different expansions, glasses united would come apart again, but that could be overcome by pressures of about 30 lb. per square inch.; strains would, however, appear during cooling, and these strains could not be eliminated by annealing. Yet such welds might answer. More serious was the fact that the glasses might differ by 200 deg. C. and more as to their annealing-points; yet in many cases suitable glasses could be selected. Glasses which would not fuse together in the blowpipe flame could not be welded. Crown-glass and plate-glass windows had been united to a cell at 400 deg., however, the optical surfaces remaining unchanged. On the other hand, an attempt to weld object-glass combinations, lenses of flint and crown glass, had failed. In that case the parts had been clamped together at the edge at three equidistant points; perfect union had been obtained at these points at 475 deg., when the flint lens softened; but there was no general union, and both the lenses had been found to be strained. Success was again realised, however, with polarimeter tubes of soda-lime glass, to which a plate-glass window was welded at 470 deg. There was perfect union, and not sufficient strain to interfere with the measurements of rotation. Such polarimeters (see Fig. 7), with permanently-fixed windows, were very convenient, and could easily be cleaned—a point about which opinions may differ. Mr. Dalladay added that they were now trying to apply this construction to jacketed tubes of the Liebig condenser pattern which would withstand high temperatures; any hot liquid might be circulated in such a jacket, whilst corrosion of the cement by hot liquids had frequently to be feared.

Finally, Mr. Dalladay referred to the union of fused silica objects. Higher temperatures were required, but temperatures above 1,200 deg. C. had to be avoided, lest devitrification of the silica set in. In one of their experiments they had formed a cylindrical cell (for the study of ultra-violet absorption spectra of liquids), consisting of a ring of silica, 1 in. in diameter, 0.5 in. high, and two plates of silica glass, 0.75 by 0.5 by 0.1 in. The parts were held by a steel clamp and heated to 1,030 deg. for one hour. The cell had broken during cooling, because the steel frame contracted; but the fragments had shown complete union, though a higher temperature, perhaps of 1,100 deg. C., might be preferable.

During the discussion of the paper by Dr. Rosenhain, Dr. Harker and others attention was drawn to the importance of cleaning the surfaces thoroughly, —which Mr. Dalladay had himself accentuated though he had not found that the chemical cleaning

FIG. 5.

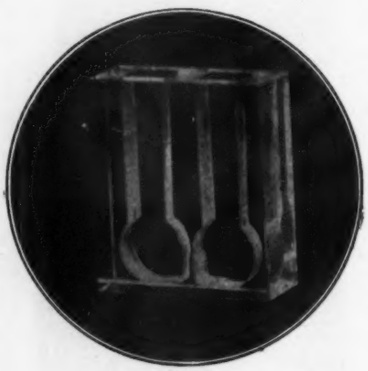


FIG. 6.

FIG. 7.

suggested gave better results—and of the influence of the moisture or hydrate film on the surface of the glass. Glasses are known to be hygroscopic, and the discharge of that moisture, first near 100 deg. C. and again at much higher temperature, had much disturbed Dr. Harker's experiments with the somewhat primitive Röntgen tubes of the early days. Dr. Harker also thought that the new glass welding would prove valuable for improving gun-sights; the parts of those sights were sometimes dislocated by the heavy jar of the gun discharge. Mr. Dalladay did not consider that the moisture film gave any trouble; yet without that film the whole process might be less difficult and delicate.

Professor A. W. Porter, who was in the chair, suggested that it might be the peculiar condition of the surface layer which made union possible at temperatures so much below the melting-point. The surface layer, to the depth of a comparatively small number of molecules probably, was under atmospheric pressure, whilst the pressures in the interior of the glass amounted to thousands of atmospheres; there was hence much greater mobility in this surface film. Reference was also made to the interesting fact, pointed out on another occasion by Dr. Rosenhain, that cracks produced in glass by the diamond would heal up to a certain extent; at any rate a scratched glass would not break an hour after having been cut. Most workers will agree with Professor Porter that cements are on the whole a nuisance. We should remark that neither Mr. Dalladay nor the other speakers used the term glass "welding;" but the term may, we think, be justified.

WOOLWORTH BUILDING, NEW YORK.

By FRANK W. SKINNER, New York.

(*Continued from page* 3.)

Pier Construction.—The pier forms were accurately located, built up to a convenient height, filled with concrete, stripped, and the caissons sunk by interior excavation. The design of the piers was such that no permanent timber or temporary material of any sort was included in their construction, the working chamber and cutting edge themselves forming part of the finished pier and homogeneous with it. This was effected by making it entirely of concrete, with sufficient reinforcement to endure sinking stresses. Concrete was cast in light temporary forms, which were removed and used over again, and at the end of this work had considerable salvage value. The wooden forms for the rectangular caissons were built complete at the contractor's yard several miles away, they weighed up to 10 or 12 tons each, and were delivered by trucks to the building, where they were unloaded and set in position by the derricks.

As the interior walls and ceilings of the working chambers were made for convenience with offset horizontal and vertical faces, their forms were made like inverted flights of stairs in convenient sections, shored up from the bottom to support the heavy load of wet concrete and easily knocked down and removed after the concrete had set.

The outside forms for the circular caissons were all made of steel plates in 3 ft. high courses riveted together in semi-cylindrical sections and connected by bolts through exterior vertical and horizontal flange angles. The interior forms for the circular piers were also made of steel plates and were shop-riveted in sections of several standard interchangeable sizes which could easily be combined and assembled for the construction of any required pier. As soon as the interior and exterior forms were assembled for the working chamber of the pier or pneumatic caisson, vertical and inclined reinforcement rods were set in them.

The interior forms, together with the reinforcement rods required for the walls and cutting edge of the working chambers, were assembled on the working platform at street level, were lifted bodily, and set within ¼ in. of the required position by the derrick booms. An allowance of about 2 in. was made in their location to provide for anticipated drift in sinking. In one instance, where no delays were encountered, the interior form and the reinforcement bars for a pier 12¼ ft. in diameter were assembled and set into position in the bottom of the excavation in half an hour. As soon as the interior form was fixed in its position the courses of the exterior forms were assembled around it and it was filled with 1:2:4 Portland cement concrete made with sand excavated at the site and gravel up to 2 in. in diameter. As the sand was excavated about as rapidly as required, only about 40 yards of it were kept in storage, while about 500 yards of gravel were stored in a bin under the street-level platform. The concrete was mixed in two machines, which delivered to one-yard buckets distributed on flat cars on a 24-in. industrial track or delivered directly to the forms by the derrick booms. The general arrangement of the plant will be seen from Figs. 3 and 4 on Plate II, published with our last issue.

Concrete was usually deposited in forms up to a

height of 25 ft., and after this had set the forms were shifted upward and piers were built to a maximum height of 50 ft. before sinking was commenced. When this height was not as great as the required height of the pier the remaining portion was built after the piers had been sunk a considerable depth. Often the finished top of the concrete pier did not reach nearly up to the bottom of the excavation, and in such cases the exterior form was continued up above the surface of the ground by a similar construction, which served as a temporary cofferdam, excluding the earth and sand and water and removed before the completion of the work. Access to the working chambers was provided by collapsible steel shafts built on the centre lines of all the piers. Some of these shafts were of horseshoe-shape cross-section. Others were oval, permitting the use of the 28-in. steel buckets. All the shafts were collapsible and were removed before the piers were filled with concrete.

Caisson Sinking.—After the piers were stripped men entered the working chambers through the open air shafts and "ditched" them by excavating the bottom to the cutting edges and down as far as permitted by ground-water level, the material being shovelled into steel buckets and hoisted in the usual manner. When further excavation was prevented by the water, steel air locks were placed on the tops of the shafts, the doors closed and air pressure sufficient to expel the water under the cutting edge was admitted to the working chamber. Under this constantly increasing pressure, which in some cases finally reached a maximum of 47 lb. per square inch, the excavation and undermining of the piers was continued with such rapidity that in one day a pier 6½ ft. in diameter was sunk 80 ft. and to a depth of 113 ft. below the curb in 20 consecutive hours. Another pier, 9 ft. 9 in. in diameter, was sunk and the concreting completed in 12 days after placing the cutting edge.

As many as nine caissons were under air pressure simultaneously, and the caisson work was carried continuously by three 8-hour shifts, each of them employing 125 "sand hogs." The caissons were sunk through coarse sand, fine sand, water and quicksand to a 6 to 8 ft. thick stratum of hard granite boulders and through it to the very irregular surface of the hard rock at an average depth of 120 ft. below the curb. Where the surface of the rock was steeply inclined it was stepped off in horizontal offsets to provide satisfactory bearing for the concrete in the working chambers.

In order to overcome the skin friction large quantities of 1 and 2-ton cast-iron blocks—sometimes as much as 800 tons—were loaded on the tops of the caissons for ballast, and the air pressure in the working chambers was reduced from time to time to assist in dropping them down. Spoil was hoisted through the air shafts in cylindrical steel buckets of 1 yard capacity, which were dumped by the derricks into the elevated storage hoppers. In one case 375 yards of material were excavated from one caisson in 24 consecutive hours. As fast as the rock bearing at the bottom of the caisson had been prepared, inspected and approved the working chambers of the caisson were filled with concrete and sealed under an average pressure of 40 lb. per square inch, which was allowed to remain on them until the concrete was fully set. Afterwards the pressure was released, the air locks and steel collapsible shafts were removed, and the wells in the piers were filled with concrete under atmospheric pressure. As fast as the concrete piers were completed steel caps were placed on them and received vertical shores, which supported the outer ends of the needle beams carrying the walls of adjacent buildings. This released the jack screws and crib work previously serving the same purpose, and maintained the walls in safety until it was convenient to build permanent underpinning foundations for them.

Air Supply.—The air-compressing plant consisted of three machines having a combined capacity of 6,000 cub. ft. of free air per minute and capable of supplying air at 50 lb. pressure to 10 caissons simultaneously. The air, delivered from the machines at a temperature of about 150 deg., was passed through an air cooler, which reduced it to about 65 deg. in the caissons.

The compressed air was stored in a receiver of 500 cub. ft. capacity and thence distributed through an 8-in. main 600 ft. long, with 4-in. branches to the caissons. Each caisson was at first provided with a pressure gauge having the needle arranged to make electric contacts at required maximum and minimum pressures and thus operate pneumatic valves which opened and closed the steam valves and started and stopped the pressure as required. This governed the pressure in the caissons to within 1 lb. of the required amount, no matter what was delivered to them. Later each caisson was provided with an automatic reducing valve, regulating the pressure as required by the depth and external water.

The compressors were operated by steam purchased from a corporation, and an auxiliary emergency supply was provided by a battery of three 175-h.p. boilers, which produced steam up to 150 lb. for rapid hoisting purposes. When these boilers were fully occupied with the hoisting engines they consumed about 20 tons of soft coal in 24 hours.

Water under city pressure was used first for cooling the compressed air, then passed through the feed-water heater, and finally used for concrete mixing, making a considerable economy as well as warming the concrete in cold weather. The principal quantities involved in the construction of the sub-structure included about 60,000 yards of excavation, 24,000 yards of concrete, 75,000 ft. board measure of lumber in the forms and 250,000 ft. board measure of lumber in the platforms and bracing, and 300 tons of reinforcement steel.

The other principal items of plant installed included a 7 by 21 ft. steel air lock for hospital purposes, where a physician and nurse were always in attendance, 10 hoisting engines all equipped with swinging gears, 3 steam pumps, many pulsometers, 2 feed-water heaters, 10 flat cars for transporting concrete buckets, 10 steel concrete buckets, 9 air locks with counterbalanced doors, 540 linear ft. of air shafts, 250 tons of standard steel forms and cofferdams, 250 tons of pig-iron ballast, and 1,000 tons of cast-iron ballast blocks.

Many of the methods most successfully used in the substructive work were those that have been developed and advantageously practised by John F. O'Rourke and by the Underpinning and Foundation Company, both of New York, who are among the most brilliant and eminent contractors for important work of this nature.

Excavations around the Caissons.—The top of the lowest floor of the building, that of the boiler room, is 42 ft. below the curb, 12 ft. below original water-level, and about the same distance below the bottom of the general open excavation. There were about 30,000 cub. yards of sand and quicksand below water-level, which were removed entirely by hand. After the caissons had been sunk and the basement floor constructed the remainder of the excavation was made in drifts like those of tunnels, and the sand was shovelled into steel buckets of 1 yard capacity, which were pushed on flat cars over 24-in. industrial tracks laid to four hoists, by which the buckets were elevated to 25-cub. yards storage bins, from which wagons at street level were loaded by chutes.

The hoisting apparatus was a very simple construction, consisting merely of two vertical guides and a hoist line slightly inclined from the vertical. A horizontal steel bar about 4½ ft. long was bolted to the bail of each bucket and projected beyond it to engage the faces of the guides through short vertical rounded steel shoes pivoted to the bar. The horizontal reaction due to the inclination of the hoist line held these shoes firmly against the surfaces of the guides and kept the buckets in position. At the top of the hoist the guides were curved horizontally so that the buckets followed over them and swung out and dumped over the top of the adjacent receiving hopper. When the latch was tripped the bucket automatically reversed, discharging its contents into the hopper, and when relieved from its load revolved back into vertical position by gravity and descended for another load.

Retaining Walls.—The lower portions of the exterior walls sustain a heavy exterior pressure and are made of concrete having a maximum thickness of about 3 ft. and reinforced by vertical I-beams. They are carried to an extreme depth of about 45 ft. below the curb or 5 ft. below the ground-water level, in trenches sheeted down by the contractor for the sub-structure and drained by pulsometers. The spaces between these walls and the temporary steel sheet piling that lined the main excavation were back-filled by flushing in sand mixed with about one barrel of cement per cubic yard. The sub-basement walls contain about 2,500 yards of 1 : 2½ : 5 Portland cement concrete made of 1½ in. broken stone, machine-mixed and delivered in wheelbarrows on runways supported every 5 or 6 ft. by the horizontal and inclined braces for the exterior sheet piling. The concrete was made waterproof by grinding 2 per cent. of Toch cement with the clinker used in the manufacture of the Portland cement.

(To be continued.)

THE UNIVERSAL GRAVITY BUCKET CONVEYOR.

By GEORGE FREDERICK ZIMMER, ASSOC.M.INST.C.E.

GRAVITY bucket conveyors, one of the best mechanical devices for charging coal bunkers in power stations and gas works, have of late years been less frequently employed than was formerly the case, and their rightful place has, to some extent been taken by the separate elevator and conveyor which they formerly superseded. The reason for this is twofold. In the first place gravity bucket conveyors are expensive in first cost, since they run at a slow speed, say, 40 to 60 ft. per minute, and must therefore be of comparatively larger dimensions, to handle the same amount of coal, than faster-running devices; and, secondly, owing to their lack of flexibility to accommodate themselves to the relative positions of existing buildings, which may have been laid down without due regard for mechanical equipment for handling the coal. The first objection is short-sighted, for in both power stations and gas works which provide for domestic as well as for town lighting, and for electrical traction, where a breakdown might be disastrous, the most reliable conveyors and not the cheapest conveyors are the best for obvious reasons. As regards the second objection, this is more justified, for if the coal store and boiler, or retort houses, are not all end-on, tandem fashion, with the railway siding (on which the coal arrives), at right angles to them at the coal store end, an ordinary gravity-bucket conveyor cannot be installed without difficulties, while, with a couple of independent conveyors and an elevator, all separately driven, the difficulty may be solved and the relative position of the buildings is then immaterial.

A gravity bucket conveyor of a more flexible construction, one which can work not only in one vertical plane, but in any number of planes, would overcome all difficulties under the second head. At the time when gravity bucket conveyors were first introduced it was often argued that a separate elevator and a separate conveyor would, in case of a breakdown, keep the installation at least partly available, while a breakdown of a gravity installation meant a complete interruption. But the experience gained since with gravity bucket conveyors has proved that they are perhaps the most reliable conveyors, and owing to their slow speed of travel a breakdown is very seldom heard of, so that the wish of the competitor may have been the father of such thought. Besides, if the elevator of such a combination of elevators and conveyors should break down the conveyor would be no use by itself, and if the conveyor broke down the utility of the elevator alone would be small, as it could fill but a very small proportion of the coal store.

Three types of gravity bucket conveyors which possess this greater flexibility have been introduced on the Continent and have been in use for a sufficient length of time to prove their reliability. The best of the three, in the writer's opinion, is that patented by Bleichert, and as the British Ropeways Engineering Company, Limited, of 34, Fenchurch Street, London, have recently purchased the business of the Bleichert Aerial Transporter, Limited, from the Controller appointed by the Board of Trade, a special interest attaches itself to this machine. We may shortly see it manufactured in this country, so that a closer investigation of the principle cannot fail to be of interest. One of the chief features of the "Universal Conveyor" (as we will call it) is that, unlike all other gravity bucket conveyors, it has one single rail-track and one single chain only, instead of the necessary two of the other types. This one central rail and chain permits of great flexibility, and curves not only on an horizontal but practically on any other plane or number of planes can be negotiated. Each unit of the chain, with its pair of buckets, one on each side (see illustrations on pages 26 and 27) has one central running wheel only, instead of the usual two or four. This single rail and chain and one wheel for each unit reduces all

UNIVERSAL GRAVITY BUCKET CONVEYOR.

CONSTRUCTED BY THE BRITISH ROPEWAY ENGINEERING COMPANY, LIMITED, LONDON.

Fig. 1.

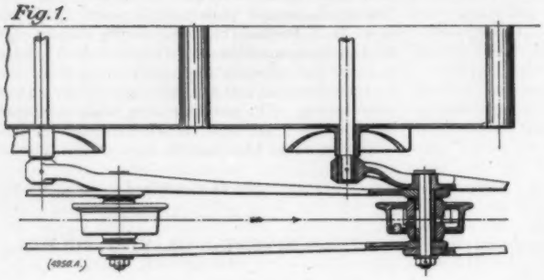


Fig. 2.

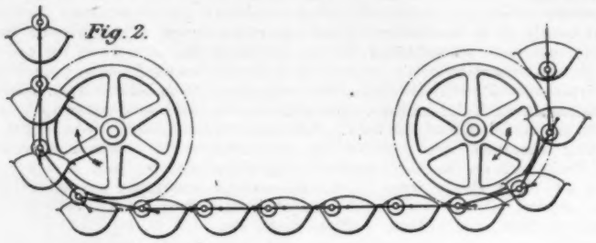


Fig. 3.

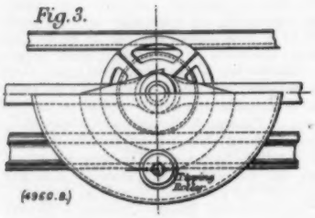


Fig. 4.

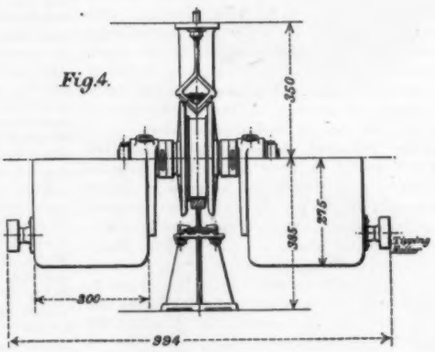


Fig. 5.

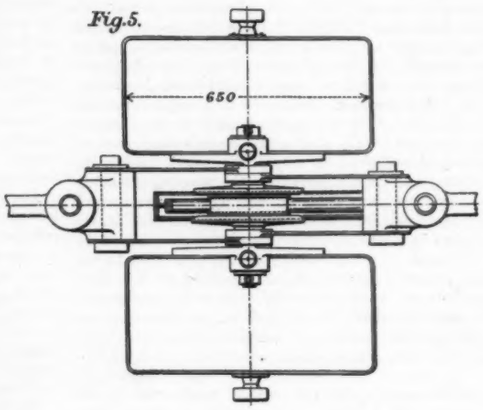


Fig. 6.

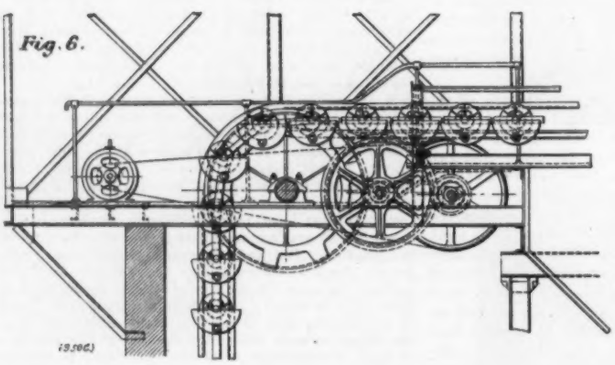


Fig. 7.

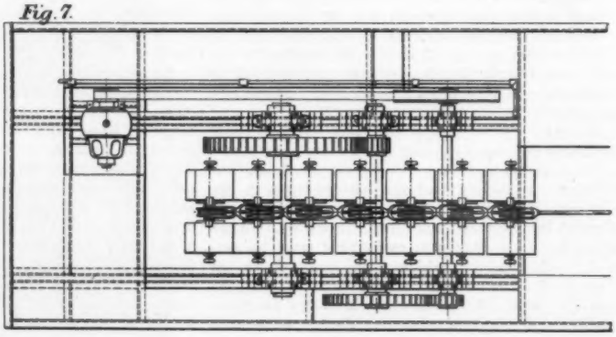


Fig. 8.

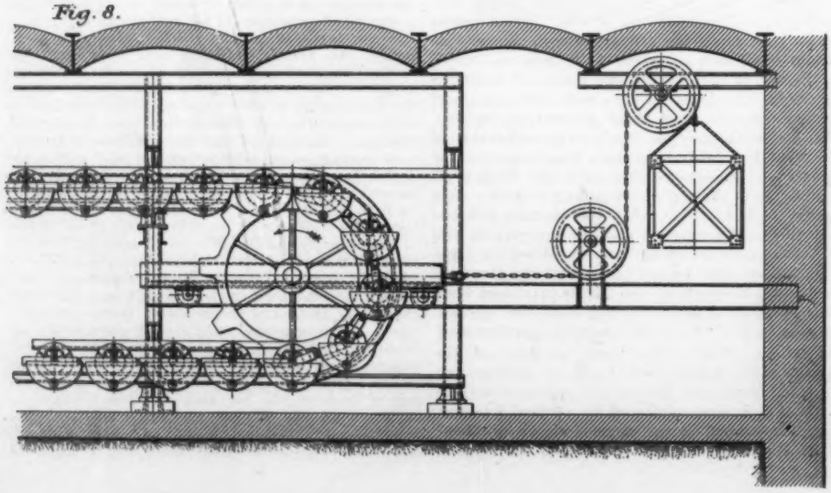
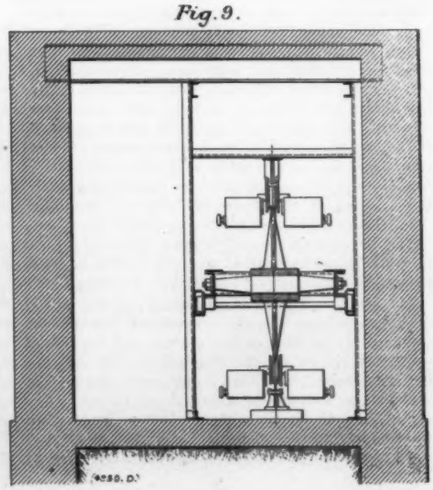


Fig. 9.



UNIVERSAL GRAVITY BUCKET CONVEYOR.

CONSTRUCTED BY THE BRITISH ROPEWAY ENGINEERING COMPANY, LTD., LONDON.

Fig. 10.

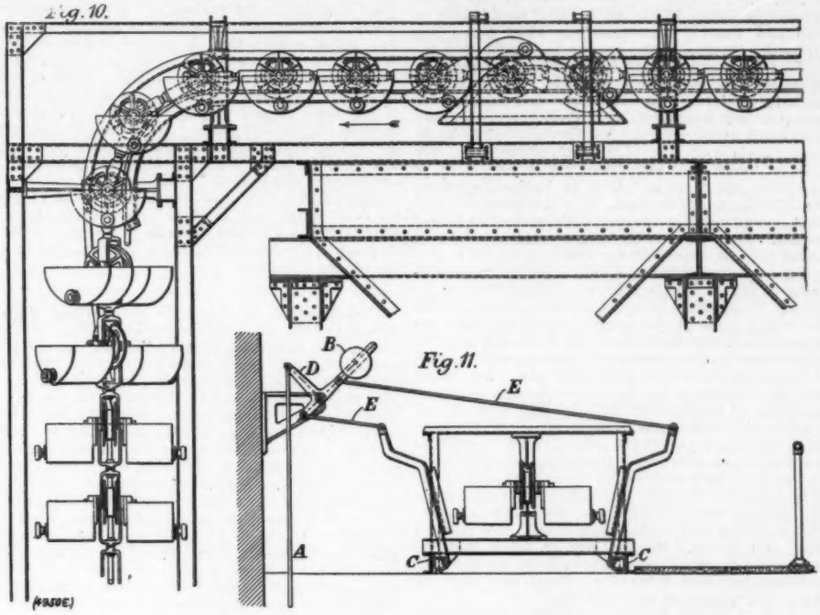


Fig. 11.

Fig. 12.

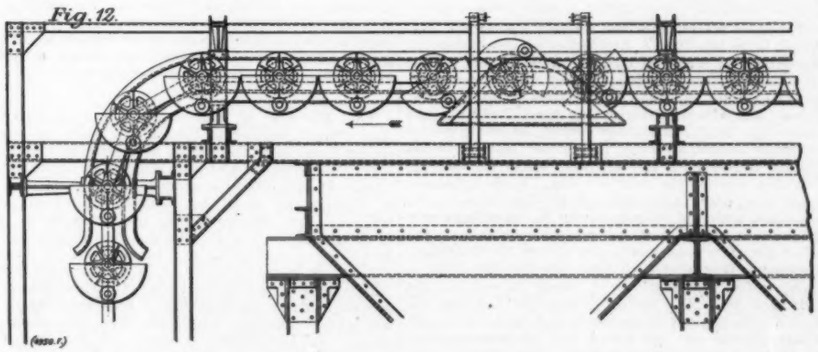


Fig. 13.

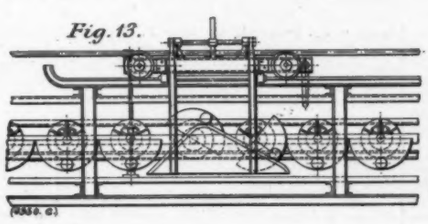
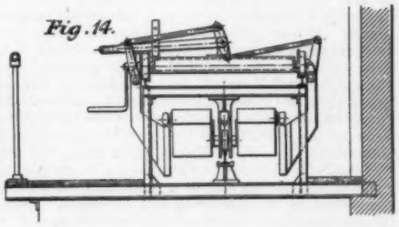


Fig. 14.



resistances when passing corners and curves, in fact, all frictional resistances, and therefore wear, to a minimum, and incidentally the chain need not be kept as taut as usual. In common with all gravity bucket conveyors, so also here the buckets are suspended free-swinging above their centre of gravity, that is in stability, so that the chain of buckets, in whatever direction it may travel, cannot spill its load even if the chain is upside down in its horizontal run. Although the buckets are in stability upon their wheels they are unstable on their rail, and as one of the pair of buckets may sometimes contain a heavier load than the other it is necessary to employ, for the horizontal runs, a second upper and also central rail, to force the chain of buckets to run absolutely upright, in case of any tendency to do otherwise.

The single chain of such a conveyor must combine the inherent advantages of a chain with the flexibility of a rope, the links must therefore either be joined together alternately with horizontal and vertical pins or bolts, or the connecting bolt of two adjacent links must lie in the axial direction of the chain, with just sufficient play to permit of the universal motion, be this ever so slight. In all gravity bucket conveyors, even in those with a single chain, the links of that single chain, or the more usual pair of chains, surround the buckets completely. This necessitates a central spindle upon which the bucket is suspended above its centre of gravity. With the conveyor under consideration this is, of course, impossible, and the buckets must therefore be divided into two units of only half the size, one on each side of the central chain. The great advantages of this construction consist not only in dispensing with the spindle (which usually traverses the centre of the bucket and which therefore obstructs the filling, especially when large coal has to be handled), but that the tripping device can approach the buckets unobstructed on either side without being encumbered by an enclosing chain link, as we shall presently see.

All conveyors which are suitable for traversing more than one plane must either effect the change from one such plane into another by a twist during a vertical ascent, or by passing curves in an horizontal plane. The latter is most rarely necessary, so that the former expedient will suffice in 99 cases out of a hundred. Now we must admit that a slight twist in the vertical stand of an ordinary gravity bucket conveyor is possible, but the latitude is so small that a very long vertical run, say of about 40 ft., is necessary to permit a twist of 90 deg. That is, if a conveyor is running north and south in its lower run and is to continue at the top of the bunkers in an easterly and westerly direction, it can be done by the ordinary gravity bucket conveyor if the vertical ascent is long enough to permit the twist; while with the "Universal" type the twist can take place in a few feet easily, as shown in Fig. 10. We must here also bear in mind that with the earlier type of conveyor of this class the aforementioned twist depends not on properly constructed joints, but rather on poor fit, and the poorer the fit the easier it is to accomplish the twist in the vertical run.

If we insist upon a bend in an horizontal plane the buckets must be some distance apart to permit such a bend. If as we might well do, we dispense with this, the buckets can touch each other in an unbroken continuity, which gives larger capacity, and which completely dispenses with complicated feeding devices. With a continuous and unbroken chain of buckets the lower strand of the conveyor can be fed by a simple shoot, or in this particular case with a double shoot, one for each side. With buckets, say, at every alternate link, devices must be introduced either in the form of a series of funnels travelling above and with the buckets for a short distance, by which funnels the buckets are fed, or shoots which reciprocate from one bucket to the next and thus dole out intermittently a load to each. The difficulty of such constructions is apparent, especially if large coal has to be handled, and as the conveyor can thus be fed only at a comparatively slow speed it reduces the capacity of a machine to that extent, the feeding device constituting the neck of the bottle.

The tipping or emptying of the buckets of the "Universal" conveyor is exceedingly simple, particularly as the tipping rollers are unencumbered by parts of the chain, as already hinted at, and therefore of ready access by stationary and travelling trippers. For the same reason they can be tipped to a greater angle, and therefore more effectually emptied, even if of a semi-cylindrical form, which is usually employed, and as shown on the drawings. The advantages of having the buckets so close together that they touch each other has already been mentioned, but it is not sufficient for them merely to touch, as it is almost impossible to get them close together when new, and the least wear in bucket or chain would leave in any case a small gap for coal dust to fall through. So the buckets must overlap. This was realised long ago, and much thought and ingenuity have been bestowed upon this detail of gravity bucket conveyors. It is easy enough to make the buckets overlap just slightly, but without special precautions they will get out of position when travelling empty on their return journey. In one type of the gravity bucket conveyor this difficulty has been overcome by making the two chains of half the pitch of that of the bucket, so that the intermediate joints of the chain coincide with the junction of every two buckets, and by providing a common joint-pin for the two links (one on either side of the bucket) this pin ingeniously covers the space and thus prevents spilling. In another instance a tiny auxiliary bucket is placed beneath the gap, and catches any fine coal spilt, and as this is fixed, and not swivelled to the chain, it will empty itself during the ascent into the next succeeding bucket.

A great deal of ingenuity has been bestowed on the American gravity bucket conveyor known as the "Peck" Carrier (so named after Staunton B. Peck, vice-president of the Link Belt Co.), to free the overlapping buckets as they assume their bottom vertical run; they are suspended from arms projecting 6 in. at the rear of the joint-pin of the chains (see Figs. 1 and 2). As the chains pass round the bottom corner wheels the buckets move in the arc of a circle of a larger radius than the joint-pin, they are therefore automatically separated at this point and assume their correct position when again on the straight run. However much we may admire this solution it is rather complicated, and the designer of the "Universal" conveyor had the good fortune to overcome the same difficulty with a minimum of trouble by a stationary tipping device, similar to that employed at the discharging point. This tips the buckets as they pass the bottom corner of the empty strand prior to the commencement of the lower horizontal run where the conveyor is fed, and during this tipping of each succeeding bucket they arrange themselves with the overlap in the right way without any confusion. The overlap is so slight that it has not been attempted to show it in the illustrations.

Figs. 3, 4 and 5 show one unit of the chain of buckets of this "Universal" conveyor, with the supporting rail below the guide wheel and an angle-iron rail above. These rails are only necessary in the horizontal runs, the vertical runs not requiring any rails whatever. The wheel is bushed and the supporting spindle is

hollow to give access for lubricant to the wearing parts, or the spindle is sufficiently hollowed out to contain enough viscous grease to allow the conveyor to run for twelve months, daytime only, or six months when running night and day.

The chain shown in these illustrations is intended for a conveyor which is able to pass round a curve in the horizontal run; the buckets are some distance apart, and the chain is joined together with horizontal and vertical pins alternately; the buckets are attached by substantial cast-steel brackets. At the extreme outside of each bucket is a small tipping roller which engages with the tripper at the delivery point. It will be seen from the illustrations that there is no part of the chain which can interfere with the access of these small rollers, and this, as has been pointed out, is a great advantage for the tipping device. When no horizontal curve is required the buckets are placed close together, and in this case the method of joining them up is by an axial bolt, which can be best seen in Fig. 10.

The driving gear for such an installation may be arranged as shown in Figs. 6 and 7, on page 26. The electric motor drives on to a countershaft which gears into a second, and finally into the main conveyor spindle, reducing the speed at each point. Figs. 8 and 9 show the tightening gear, which is mounted on a carriage and rails, being kept taut by a heavy weight.

The approach of the vertical strand to an upper horizontal one may be seen in Figs. 10 and 12, the former also show that if needs be the twist can be accomplished in a very short length. The bend in the conveyor is effected by the rails without the agency of a corner wheel. In Fig. 12 a conveyor working in the same plane may be seen. This also shows the way in which the rails end, leaving the vertical run unsupported by rails.

In Figs. 10, 11 and 12 stationary tripping devices are shown, the tripper planes being formed of angle iron riveted in a parabolical form to the side levers, which are hinged at their lower ends CC, and which are bound to move together in and out of gear by the rod A, bell crank D, and rods E. The tripper is kept in or out of gear in its two extreme positions by the weight B. In Fig. 11 the tripper is shown out of gear, whilst in Figs. 10 and 12 it is in gear and three buckets are in the act of being tipped and righted again.

Figs 13 and 14 show another method of hinging the tripper from above, in this case the appliance is mounted on wheels running on two small rail tracks above the conveyor and the tipping gear is suspended also from above. The hand crank shown in the cross-section Fig. 14 is for the purpose of moving the carriage by rack and pinion to any other spot where it can be fixed to the rails by clamps. It will be seen from the drawings how simple the application of the tripper is in this case. In the older types in which the chain surrounds the bucket the tipping rollers have to be approached by the tripper from below in the very limited space between the chain and bucket With this conveyor the buckets are turned practically by 180 deg. and empty themselves perfectly.

INDUSTRIAL NOTES.

THE Minister of Munitions gives notice that in exercise of the powers conferred upon him he prohibits, until further notice, any person, firm or company from carrying out, without a permit issued under the authority of the Admiralty, the Army Council or the Minister of Munitions, any work consisting in or connected with the manufacture, assembling or erection of any new or unused motor, internal combustion engine designed or adapted for mechanical traction, or of any new or unused motor cycle, motor chassis, motor wagon, or of any tractor or other motor vehicle of any kind propelled by mechanical means, subject, however, to the following exception: work required to complete contracts placed by the Admiralty, the War Office, the Minister of Munitions, or an Allied Government on or before November 3, 1916. For the purpose of this order the expression "assembling" shall be deemed to include the placing or replacing in position of any part. The Order dated November 3, 1916, published in the *London Gazette* of November 10, 1916, is hereby cancelled, without prejudice to anything done thereunder.

The following resolution, dealing with Labour Exchanges, was passed at a special council meeting of the General Federation of Trade Unions held in London in the early part of last month:—

"That this special council meeting of the General Federation of Trade Unions views with grave apprehension the official attempts to extend the powers of the Labour Exchanges, and declares its resolute opposition to the compulsory registration of unemployed workmen at Unemployment Exchanges; and, further, it desires that no vacancies shall be registered by Labour Exchanges unless the standard rate of wages is assured."

Speaking at Manchester, on Sunday last, Mr. J. Hodge, M.P., Minister of Labour, said that one of the greatest problems which the country would have to face was that of demobilisation when peace was declared. At present the Labour Exchanges were the nucleus of an organisation for handling that problem. When he had been three days at the Ministry he told the chief official of those Exchanges that neither trade unionists nor employers liked them, and that they would only become useful when they were given heart, lungs, brain and soul—life and inspiration. The Labour Exchanges had been too bureaucratic in character, and there had been an inclination among the officials to make them more bureaucratic still. That was not going to happen again so long as he had control. These Labour Exchanges could serve a most useful purpose, especially for women workers, if they had the sympathy, the inspiration, the soul that they ought to have. Just now he was endeavouring to get all the information he could of the working of the Exchanges—and of the way in which they did not work—and in this he trusted that he would have the help of both trade unionists and employers in the work of reorganisation, reform, and stimulation. One reason why the Exchanges had failed was because managers had resented having committees to deal with, though some of those committees, he understood, did not meet from one year's end to the other. Such committees must be resuscitated, and something must be done, too, so that instead of having to travel 10, 15, or 20 miles in order to register themselves for vacancies, the lads coming home from the war, and other men and women, would find a place within, say, five miles of their own homes. He was glad to know that the manager of the Manchester Labour Exchange had both understanding and sympathy. That was what all others had to have or else clear out.

President Wilson, says the *Railway Age Gazette*, New York, is manifesting a disposition to stand firm for legislation to forbid strikes in railway-train service until there has been investigation by a board representing the public regarding the matters in controversy. Should Mr. Wilson get legislation enacted which would reduce the danger of railway strikes, he would render a public service of such magnitude that it would almost overshadow the mistake made by him in jamming through the Adamson Act. There have been some complaints from railway services because the President refrained from including, in his railway programme, a renewal of his recommendation to the effect that Congress specifically direct the Interstate Commerce Commission to take into consideration, in fixing rates, the increase in wages caused by the Adamson Act. As a matter of principle, however, the President's original recommendation as to this particular matter was not sound, and the reasons given by him for not renewing it were unanswerable. The Interstate Commerce Commission has ample authority already to take into consideration, in fixing rates, every expense properly incurred by the railways, and it is hardly conceivable that the Commission would refuse to give full weight to an increase in expenses forced upon the railways by an Act of Congress. It is proper and desirable for Congress to set forth, in general terms in the laws, the factors and elements that the Commission has to consider in fixing rates, but for it specifically to direct the Commission to consider an increase in expenses due to a piece of special legislation would be to establish a bad precedent. One of the worst faults of our system of legislation, adds the American journal, has been the too frequent interference of legislative bodies with regulative Commissions. When such interference takes place it is usually dictated by politics; and when it is dictated by politics the railways are usually the victims, not the beneficiaries of it. The railways should consistently oppose detailed interference by Congress with the Interstate Commerce Commission in the performance of its duties.

It is stated in the *Iron Age* that the shortage of skilled labour in the American shipbuilding trades is seriously affecting the progress of construction work in the Government navy yards. This constitutes a very embarrassing factor in the problem of expanding the yards, following the policy recently adopted by the Navy Department to equip eight yards for the construction of warships, according to the annual report of Admiral Taylor, Chief of the Bureau of Construction and Repair. Important recommendations are embodied in the report respecting the standardisation of all forms of material purchased by the Government and urging a large increase in the stocks of material and equipment. The greatest difficulty, Admiral Taylor says, has been found in avoiding serious delays in the construction of all the vessels now being built by Government, owing to the abnormal conditions existing in both the material and labour markets. A limited number only of skilled men was available in the shipbuilding trades, and as these men were in great demand in the various private establishments, where an unprecedented volume of merchant tonnage was under construction, it proved impracticable to obtain men to increase the navy yard forces to the point warranted by the large amount of work in hand. In fact it had been hard to avoid serious depletion of the force already employed, as the opportunities existing in private plants for increased earnings, through overtime work, formed an inducement which went far to offset other advantages possessed by Government employment. This condition promised to become more acute when the large volume of work involved in the new naval programme was taken in hand, as there appeared to be no reason to look for a decrease in the demand for additional new tonnage for the merchant marine.

The same note is struck in the *Railway Review*, Chicago, which states that a labour shortage of more or less intensity has existed for several years, but it reached the most acute stage last summer. Previous to that time the establishments were getting along as best they could, constantly decreasing the amount of work done, and hoping against hope that the labour market would loosen, so that the work could be caught up with. This condition finally resulted in the investigation and adoption of appliances which reduce hand labour. Appliances which formerly were not looked upon with great favour are now being sold in quantities because they reduce the number of labourers necessary to perform the work for which they were designed. Whenever the work is especially arduous or unpopular, there the use of labour saving appliances is gaining by leaps and bounds. Many railways have recognised the trend of the times, and have been making studies of labour-saving appliances to alleviate the shortage of labourers, but there is still much opportunity for improvement, and it behoves every railway to investigate carefully the claims of any appliances, materials or methods which promise a marked saving.

The Ministry of Munitions announces that an Agricultural Machinery Branch has been set up in conjunction with the Board of Agriculture and the Food Controller, to deal with the control of the manufacture of agricultural machinery and implements. It is intended to class the manufacture of all such machinery and implements as munitions work. Mr. S. F. Edge has lent his services to the Ministry of Munitions as director of this branch, and Mr. E. Guy Ridpath is deputy-director. An advisory committee of representatives of the agricultural machinery trade to generally advise the branch has been established, on which the following gentlemen have consented to serve:—A. Bornemann, Ruston, Proctor and Co., Limited, Lincoln; R. H. Fowler, J. Fowler and Co., Leeds; W. Harrison, Harrison, Macgregor and Co., Leigh; J. Howard, G. and F. Howard, Bedford; E. C. Ransome, Ransomes, Sims and Jefferies, Ipswich; and J. Segar, R. Hornsby and Sons, Limited, Grantham; with representatives of the Ministry of Munitions, the Board of Agriculture and the Food Controller.

In their annual report, dated the 9th inst., Messrs. Bolling and Lowe, 2, Laurence Pountney Hill, E.C., state the following:—

"The number of forecasts of 'after the war' conditions is legion, but at the present time and under existing circumstances of little value. We have to recognise the various efforts being put forth to consolidate and improve our commercial power. That a committee formed in the spring to watch over the iron, steel and engineering industries was much criticised from various points of view is incidental to all such undertakings, but it is to be welcomed for one reason, that it serves to bring forth many views on working methods, which is always an advantage, and stands a fair chance of leading to some valuable propositions that may be adopted. But more than this awaits, we hope, the exertions of the committee. We may also point to the spelter scheme as a step in the right direction. The trade bank should likewise be an additional support to the manufacturer and exporter, as the Conference of Ironmasters in Birmingham in November seemed to anticipate. We quite realise that the labour question stands out prominently as the Gordian knot which will test to the utmost the skill and patience of all concerned, and that it is hedged in with difficulties. There are, nevertheless, opinions expressed by authorities in these matters that it will, after all, prove less complex than it at present appears, and that various forces will be brought into play to assist in satisfying the demands of Labour without an unjust burdening of Capital."

YEAR-BOOKS AND ANNUALS.

Almanacks and Calendars.—We have received from Messrs. E. G. Wrigley and Co., Limited, Foundry-lane Works, Soho, Birmingham, a daily tear-off calendar. A similar calendar, giving for each day quotations from Shakespeare, comes from Messrs. Ashwell and Nesbit, Limited, steam heating specialists, London and the provinces. Messrs. Lamport and Holt have sent us one of their artistic calendars showing a number of nicely printed seascapes. The Brown Hoisting Machinery Company, Cleveland, Ohio, have issued a very clear monthly almanack, each of the 12 sheets illustrating their specialties. Other nicely printed almanacks have come to hand from Messrs. Haslam and Bretton, Limited, engineers' agents and merchants, Cardiff and Bristol; Messrs. Hulse and Co., Limited, Manchester, illustrating their machine tools; Messrs. R. Y. Pickering and Co., Limited, builders of rolling stock, Wishaw; Messrs. W. H. Willcox and Co., Limited, 38, Southwark-street, London, S.E.; the British Aluminium Company, Limited, 109, Queen Victoria-street, E.C., giving at the back the roll of honour of their staff and employees. We have also received a set of weekly card refills for their stand from the Welin Davit and Engineering Company, Limited, London; a very neat monthly calendar from Messrs. H. W. Ward and Co., Limited, machine tool manufacturers, Lionel-street, Birmingham; a monthly tear-off calendar from Messrs. Charles Churchill and Co., Limited, machine tool manufacturers, London and the provinces; similar calendars from Messrs. John Rogers and Co., Limited, Wolsingham (Durham); Messrs. Fry's (London), Limited, 46, Upper Thames-street, E.C.; Messrs. Alfred Herbert, Limited, Coventry; Mr. G. Beaufort Richards, M.Inst.N.A., Wednesbury; Messrs. Unwin Brothers, printers, 27, Pilgrim-street, Ludgate Hill, E.C.; Messrs. Harrison and Sons, printers, 45–47, St. Martin's-lane, W.C.; and the United States Metallic Packing Company, Bradford.

Diaries.—The Electrical Engineers' Diary for 1917, edited by Mr. J. H. Johnson, M.I.E.E., and issued, at the price of 5*s.*, by Messrs. S. Davis and Co., 30 and 31, St. Swithin's-lane, E.C., for the use of consulting engineers, architects, electrical contractors, central station engineers, and all users of electrical apparatus, gives a large amount of information on electricity, and on its numerous industrial applications. The subject matter, which includes also general data, an index of manufacturers according to trade names, rules and regulations concerning the use of current, information on the electricity supply in London and in the provincial towns, covers over 350 pages, followed by the diary portion of the book, arranged three days on a page. The book measures 11 by 9 in. and is issued both in stiff and in limp covers, this latter edition being for the convenience of the users who wish to take the book with them when travelling.—Messrs. Hayward, Tyler and Co., Limited, hydraulic engineers, 99, Queen Victoria-street, E.C., have sent us one of their pocket diaries for 1917, giving useful data on pumps and other hydraulic machinery.—We have received from Messrs. Thermit, Limited, 675, Commercial-road, E., one of their pocket-books, giving almanacks for 1917 and 1918, and interesting information on their welding compound.

THE LYONS INDUSTRIAL FAIR.—The second Lyons fair is to be held in that city from March 1 to March 15. Over 2,000 exhibitors of France and Allied and neutral countries have signified to the committee their wish to take part in the exhibition.

GERMAN WAR PROFITS.—The Howaldtswerke in Kiel has for the year 1915–16 earned a working surplus of 1,811,698 marks, against 1,209,738 marks for the preceding year; in addition, there are dividends receivable of 56,515 marks, against an expenditure during the previous year of 20,812 marks. The writings-off amount to 745,149 marks, against 818,797 marks for the preceding year, but of the writings-off in 1914–15, 176,709 marks were on bonds, whilst the sum for 1915–16 entirely applies to the works and the plant. The net profits have risen from 262,307 marks in 1914–15 to 1,030,661 marks for the last financial year. The dividend has been fixed at 8 per cent. on the old shares, and 4 per cent. on the 2,900,000 new shares, against 6 per cent. on the preference shares, and 5 per cent. on the ordinary shares. A sum of 250,000 marks has been reserved for war-profit tax. The report says that the company has been fully occupied during the year in question; overtime has been worked in the different departments, and day and night work has often been necessary.—The Rossleben Gewerkschaft have declared a dividend of 500 marks per share against 200 marks for the preceding year.—The United Dahlhausen Works, Bielefeld, have declared a dividend of 18 per cent. for 1915–16, against 15 per cent. for 1914–15.—The Grossmann Iron and Steel Works at Wald, Rhineland, have declared a dividend of 25 per cent. for the year 1915–16, against 8½ per cent. for the preceding year. The works continue to be fully employed, and prospects for the current year are favourable.

RECENT PROGRESS IN DREDGING MACHINERY.*

By WILLIAM BROWN, M.Inst.C.E.

THE paper deals with bucket dredgers, suction dredgers of the "cutter," "drag," and "moored" types, and dipper dredgers.

Each of these types, within its limits, is recognised as being best suited for particular classes and conditions of dredging, and the vessels described in the paper have not been selected because of any phenomenal dredging done by them, but because special attention has been devoted to their design to meet the several conditions of their intended use.

With regard to the question of dredging costs, no fair comparisons can be made unless due regard is had to all the items—labour, coal, oil and stores—and to the physical conditions met with. Comparisons are only of value when the conditions are fully explained, when all corresponding details are included in the charges, and when the methods of accounting at the various ports are reduced to common terms.

Bucket Dredgers.—The bucket hopper dredger Silurus is taken to represent the most modern dredger of the bucket type, and particulars are given of the work done by the dredgers Corozal, Kuphus and Octopus.

The Silurus is a twin-screw bucket hopper dredger built of steel to Lloyds' requirements, for the port of Bombay.

	Feet.
Length between perpendiculars	260
Breadth, moulded	46
Depth, moulded	30

The hopper has a capacity of 1,500 tons. The steam-generating plant consists of two marine cylindrical multitubular boilers, and there are two main engines of compound surface-condensing type for propelling the vessel, or for driving the dredging gear as required. The gearing between the main engines and the upper tumbler is so arranged that with a constant piston-speed of the main engines two different speeds of buckets can be obtained. Two sizes of buckets are provided, one set of 42 cub. ft. capacity for excavation in soft material, and a smaller set each of 22 cub. ft. capacity.

Clay-cutting Suction Reclamation Dredgers.—These dredgers give satisfactory results in all classes of clay, as well as in free material, and on occasion cutter dredgers have been employed on stiff blue clay and on hard chalk, which have been found a severe test of the capabilities of powerful bucket dredgers. The cost of repairs and renewals in cutter dredgers when working in hard material is less than with bucket dredgers, owing to their wearing parts being much fewer, the only parts of importance subject to hard wear being the cutter blades and liner plates of the pump, as against the buckets, pins and bushes, tumblers, and ladder-rollers of a bucket dredger.

The clay-cutting suction dredgers Jinga and Kalu, which are described, were ordered by the Bombay Port Trust for carrying out a very large reclamation scheme undertaken by them.

These vessels were designed to be capable of dredging 2,000 cub. yards of soft clay and mud per hour from a depth of 30 ft., and discharging the material so dredged to a distance of 4,500 lineal ft. on shore. The dredging depth was subsequently increased to 40 ft. Their dimensions are:—

	Feet.
Length on main deck	205
Breadth, moulded	42
Depth	13

The dredging pump is driven by a set of triple-expansion inverted direct-acting surface-condensing engines. The boilers are four in number, of the cylindrical multitubular type and provided with Howden forced draught. The cutter is of rotary pattern.

In the Twante Canal, connecting Twantewa with Rangoon, suction cutter dredgers were employed to cut the clay that formed the bank and bed of the canal and pump it through a floating pipe-line to alongside of wherever it was desirable to deposit it upon the bank, and then raise and discharge it by means of a floating terminal pontoon with a raised pipe overhanging the bank.

Three suction cutter dredgers, each with 1,000 ft. of floating pipe-line and a terminal pontoon with 80 ft. overhang, were ordered by the Indian Government. The Oswald and Campbell, the two smaller boats, both have 24-in. diameter suction and discharge pipes, and the Lees has a suction pipe 30 in. in diameter and a discharge pipe 27 in. in diameter.

Moored Suction Dredgers.—At Durban, where suction dredgers of the moored type have been employed with excellent results, the depth of water at the entrance in 1884 was 7 ft. 2 in., which had become 36 ft. 5 in. in 1914, mainly as a result of dredging. Up to the end of the year 1914 the total volume of solids removed at Durban amounted to 81,737,292 tons.

The chief difficulty of dredging on the bar at Durban is that the work has to be carried out in the open sea and subject to heavy weather. To meet such conditions, the suction pipes of the Durban dredgers are in two parts, joined together by flexible armoured piping spanned by universal joints. The upper end of the suction pipe is carried on a trunnion bearing near the deck, and the nozzle end is controlled by hydraulic hoist gear designed to maintain the two lengths of pipe relative to each other in the same line of axis when working at any depth. The hoisting gear is so arranged that when the length of pipe below the joint deviates from its axis with the upper length, the hoisting gear automatically raises the lower length, thus allowing the lower end to clear the obstruction which caused the deviation.

At Lagos, pump dredging plant is used in connection with deepening the bar at the entrance to the harbour, which has hitherto been subject to considerable fluctuations. The dredgers employed particularly for this part of the work at Lagos are the pump hopper dredgers Egerton and Sandgrouse. In their main features they are much alike, the Sandgrouse having a hopper capacity of 1,800 tons, while the Egerton's hopper capacity is 1,200 tons.

The dimensions of the Sandgrouse are—

	ft.	in.
Length	291	0
Breadth	45	0
Depth	18	9

and she is fitted with two sets of triple-expansion surface-condensing engines driving twin screws, and one set of triple-expansion engines directly connected to the dredging pump. Steam is supplied by three marine cylindrical multitubular boilers. The suction-pipe arrangement permits of entire flexibility in any direction.

The remaining dredging plant at Lagos has been principally provided with a view to the reclamation of certain swamps. The reclamation dredger is specially arranged for pumping from barges alongside by means of two independent dredging pumps so arranged that they may work either singly or in series, depending upon the distance the material is to be discharged.

The suction cutter hopper dredger for Lagos, now under construction, is fitted with one set of triple-expansion surface-condensing engines arranged to drive the dredging pump or the propeller, as may be required.

The outboard suction pipe is fitted with a special drag nozzle for use when dealing with compact sand, while a spiral rotary cutter is provided for dealing with clay and harder material.

A special feature in this vessel is that four independent automatic mooring machines, four capstans, and one steam windlass are provided for mooring purposes.

Drag Suction Dredgers.—The M.O.P. 210.C and M.O.P. 211.C are selected to illustrate the drag suction or moorless type of dredger. They were specially designed and constructed to meet the conditions prevailing at Buenos Ayres, and the character of the material there met with.

These vessels have a hopper capacity of 1,650 cub. m., and are each fitted with four sets of triple-expansion engines. The engines are arranged in pairs, so that all four sets are available for driving the dredging pump or the propellers separately, or two sets may drive the dredging pumps and two sets drive the propellers at the same time, as may be required. Steam is supplied by four cylindrical multitubular boilers.

When commencing work the vessel is steamed slowly ahead on the desired line of excavation, and the drag nozzle is lowered into the material until the inlet opening of the nozzle is completely sealed by the clay to be raised, so that the load on the hopper is made with the minimum amount of added water.

The drag suction dredgers Cormorant at Rangoon and Canterbury at Lyttelton are of the same type as those employed at Buenos Ayres. The Cormorant is 304 ft. long, 38 ft. moulded breadth, and 17 ft. 6 in. deep; hopper capacity 27,000 cub. ft., mean draught 14 ft. 3 in., and speed per hour on measured mile, 9¼ knots. She is fitted with patent steering jets, so that the vessel can be steered entirely independent of the rudder. The dimensions of the Cormorant and the Canterbury are alike. The only difference of vital importance is the arrangement of the propelling and pumping machinery. In the Cormorant one pump was fitted driven by independent engines, while two sets of engines were fitted for propelling, each driving one twin screw direct. In the Canterbury the machinery arrangements are similar in all respects to the arrangements already described for dredgers M.O.P. 210.C and M.O.P. 211.C.

Dipper Dredgers.—To illustrate this type of dredger, the modern 15-cub. yard dipper dredgers Gamboa and Paraiso, employed on the Panama Canal, have been selected.

The ability of these dredgers to dig into a bank of shale, sandstone, lignite, or any of the softer rocks, to dispose expeditiously of a rock too large to pass through the dipper, to dig to 50 ft. depth, and load into scows of almost any size, makes them very valuable tools for work of this class. They are capable of dredging 7,000 to 10,000 cub. yards of rock per day of 24 hours, depending on the degree of hardness of the material. The material handled by them is loaded into bottom-door steel dump scows.

The principal features of the Gamboa and Paraiso are the following:—

Each dredger has two dippers respectively of 15 and 10 cub. yards capacity. The dipper handle is 72 ft. long. The main hoisting engines are of the twin tandem compound type. The winding drum is graduated so as to give a low speed when digging. The swinging engine is of the double-cylinder high-pressure type, with steam-operated link reversing gear. The dredger is fitted with three spuds. The forward spuds are placed far enough back to allow a swing of 180 degrees for the boom. The third spud is placed centrally at the stern.

PROPOSED NEW COAL SYNDICATE IN GERMANY.—The owners of the coal mines in the Saar district are at present negotiating for the formation of an independent coal syndicate for the district. The contemplated new syndicate will have to act in close and constant touch with the Rhenish-Westphalian Coal Syndicate, whose prices always regulate those for the Saar district.

* Abstract of a paper read before the Institution of Civil Engineers, on Tuesday, January 9, 1917.

CARTRIDGE-CASE MAKING MACHINES.

We illustrate in Figs. 1 to 8 on our two-page plate, and in Figs. 9 to 14 on this page and pages 31 and 34, a set of machines built by Messrs. Greenwood and Batley, Limited, Albion Works, Leeds, for the manufacture of 3¼-in. cartridge cases up to a length of 11¼ in. All the drawing machines, Figs. 1 to 8, and Fig. 9, are very similar in construction and are used for the cutting out of the blanks and the vertical drawing out of the cartridge case to the required wall thickness. The machine Fig. 1 cuts out the blanks and has an automatic stop motion after each stroke. The two following ones, Figs. 2 and 3, have also an automatic stop motion after each stroke; they serve to first indent the blank, and are fitted with a device to lift the indented blank clear of the die. The machine Fig. 4, like the three preceding ones, has an automatic stop after each stroke, and is used to form the cup. The actual drawing of the cup commences on machines Figs. 5 and 6, which are double-geared vertical drawing machines with friction clutch, arranged to stop, when required, after each stroke or to run continuously. The machine Fig. 7 is a vertical indenting machine for the second indenting operation; it is arranged automatically to release the indented case in the die and to bring the case with the die forward, so that the case may readily be removed and another inserted. This machine is also arranged to run continuously or to stop after each stroke. From this, the cartridge case passes to the machine Fig. 8, which is very similar in its action to those shown in Figs. 5 and 6, for further drawing out. The final drawing out operation is carried out in the double-geared, vertical-bearing drawing machine, Fig. 9, annexed, which is arranged to run continuously or to stop after each stroke. All these machines are mounted in a line in the shop.

From the machine Fig. 9 the cartridge case passes to the machine Fig. 10, on page 31, in which it is cut to length before the heading operation. This machine is hand-controlled, the cartridge case being held up to the revolving mandril by spring pressure until the surplus metal is cut off by the circular cutter mounted on the cross slide, when the attendant releases the spring catch and withdraws the trimmed case. On leaving the trimming machine the case is passed to a heading machine, shown in the two views Figs. 12 and 13, page 34. This machine has a double action; first the head is formed on the indented case and then the case is forced partly out of the heading die, from which the attendant removes it. The machine is hand-fed, and the cartridge cases are inserted as well as removed from the die by the attendant. The cartridge case is now passed on to the tapering machine, where it is partly tapered before the head and body are rough turned. The case is again tapered a second time in the machine Fig. 11, on page 31; this machine is also hand-fed, and has an automatic ejector for forcing the cartridge case partly out of the tapering die. The cartridge case is then passed to the combined head-turning and cutting-to-length machine, Fig. 14, where the head and body, as well as the detonator chamber, are finished machined.

These operations being completed, the cartridge case is washed, gauged, and, if correct, passed into the warehouse for transportation to the filling factories.

CHROMIUM AND CHROMIFEROUS IRON ORES.

Chromium for industrial purposes is obtained mainly from chromite; broadly its composition is $FeO.Cr_2O_3$, in the relative proportions of 32 per cent. of ferrous oxide (FeO) and 68 per cent. of chromic oxide (Cr_2O_3). But the ores vary within wide limits from a maximum of 68 per cent. down to 10 per cent. of chromic oxide, though generally ranging from 40 to 60 per cent., whilst the ferrous oxide content varies from 10 to 50 per cent. Chromite for commercial purposes is obtained from two sources: generally from isolated pockets, somewhat as hematite iron ore occurs in the Furness district around Barrow, and from chrome sands or placer deposits found along river valleys, the results of the weathering of igneous rocks at higher levels. The bulk of the world's output is obtained from the former. Arising from the fact that deposits of chromite generally occur in lenticular masses, the mining of this material is attended with great uncertainty, and no estimate can be made of the quantity in any deposit beyond what can actually be seen. Ferro-chromium may be described as an electric furnace output. Chromium can also be brought to the melting-point by the heat resulting from the alumino-thermal reaction.

For the production of chromium several varieties of chromium ores are available, but only two of them are of commercial value:—First, chromite as mentioned above, a compound of ferrous oxide and chromium sesquioxide, containing theoretically 46 per cent. or somewhat more of metallic chromium; and, secondly, chromiferous iron ores, which may contain 50 per cent. of iron and 2.5 or 3 per cent. of chromium. They occur both massive and granular. Chromium sesquioxide crystallises in octahedra, and is usually of an iron-black colour, very similar to magnetite; it is brittle and the fracture is uneven. It is infusible by ordinary methods; the streak it produces is brown; it has a sub-metallic lustre, the hardness is approximately 5.5, and the specific gravity is 4.32 to 4.55. It is occasionally found very slightly magnetic, but if pulverised and heated for some time chromite becomes magnetic. It is insoluble in acids. The boiling-point of chromium when vaporisation becomes sufficiently vigorous to project drops of metal from the surface, has been determined by means of an optical pyrometer to be 2,200 deg. C. The melting-point is 1,515 deg. and the specific gravity 6.92. The atomic weight of chromium is 52.1.

Chromic iron ores are used for the most varied purposes in many industries; there is a large demand for making refractory chrome bricks and furnace linings, for producing a variety of alloys, in manufacturing steel for cutting tools and automobiles, steels for jaws, balls, linings of crushing machinery and dies, and a number of special steels.

Even impure crude ore may be used as a furnace lining, ores containing as much as 8 per cent. of silica being available. Chromite is also made into bricks by admixture with tar, lime, bauxite or kaolin. The increasing use of electric furnaces for smelting metals has resulted in a large demand for chrome bricks to line the walls of basic furnaces above the slag line. Chrome bricks have been found to be too soft under heat for use in high walls, but they are useful in the low walls of electric furnaces, presuming that there is no objection to a small quantity of chrome being reduced from its oxide into the steel or other metal treated. As the chrome ore of which the bricks are made is neutral to bases and acids, the slag does not cut the banks when it drops on them, and the chrome brick walls are not cut by the molten silica which runs over them from the fluxing of the silica roof, as is the case with magnesia bricks.

An important use of chromium ores is for the production of chromates and chrome pigments. Potassium dichromate is employed for the production of chrome yellow and chrome orange; a red is also obtained. Chromium sesquioxide is a valuable green pigment. It is essential to note that chromium is a constituent of two classes of colouring materials, namely pigments and dyes. Chromium salts, such as the sulphate and chrome alum, have been largely employed in some of the processes for tanning leather. Chromium is useful for many other minor metallurgical and chemical purposes.

Chromium electro-plating is both durable and sightly, in the opinion of many experts it almost equals platinum plating, and for many purposes it excels nickel, but time and experience are yet necessary to perfect the process.

The more generally known chromium alloys are ferro-chromium, ternary chromium steel, quaternary chromium steels, such as chromium-nickel steel, chromium-tungsten steel, chromium-manganese steel and chromium-molybdenum steel; chromium has also been alloyed with other metals in cases where great hardness is required; it alloys with vanadium, but the high fusing-point of the latter renders this a difficult process. Ferro-chromium alloy carrying 6 to 8 per cent. of carbon, known as "high carbon ferro-chromium," can be produced at a low cost in crucibles, cupola furnaces and blast-furnaces, as well as electric furnaces. On the other hand, low carbon ferro-chromium commands three to five times as high a price, owing to the fact that it is so extremely difficult to decarbonise the raw product.

A chromium alloy, of which the following is the

CARTRIDGE-CASE MAKING MACHINERY.

CONSTRUCTED BY MESSRS. GREENWOOD AND BATLEY, LIMITED, ENGINEERS, LEEDS.

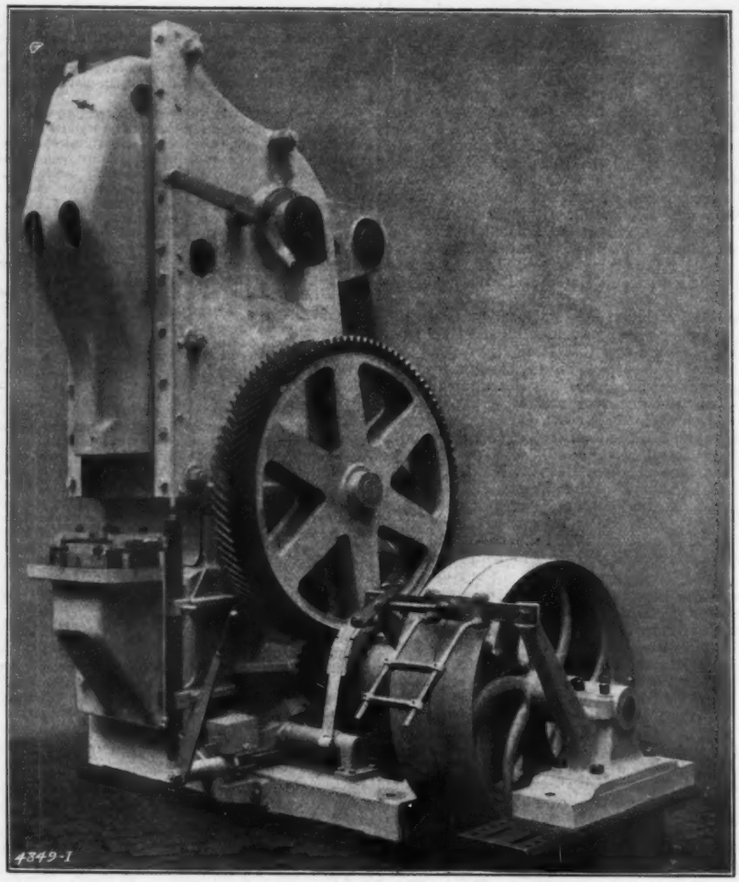


Fig. 9. Double-Geared Vertical-Bearing Drawing Machine.

CARTRIDGE-CASE MAKING MACHINERY.

CONSTRUCTED BY MESSRS. GREENWOOD AND BATLEY, LIMITED, ENGINEERS, LEEDS.

(*For Description, see opposite Page.*)

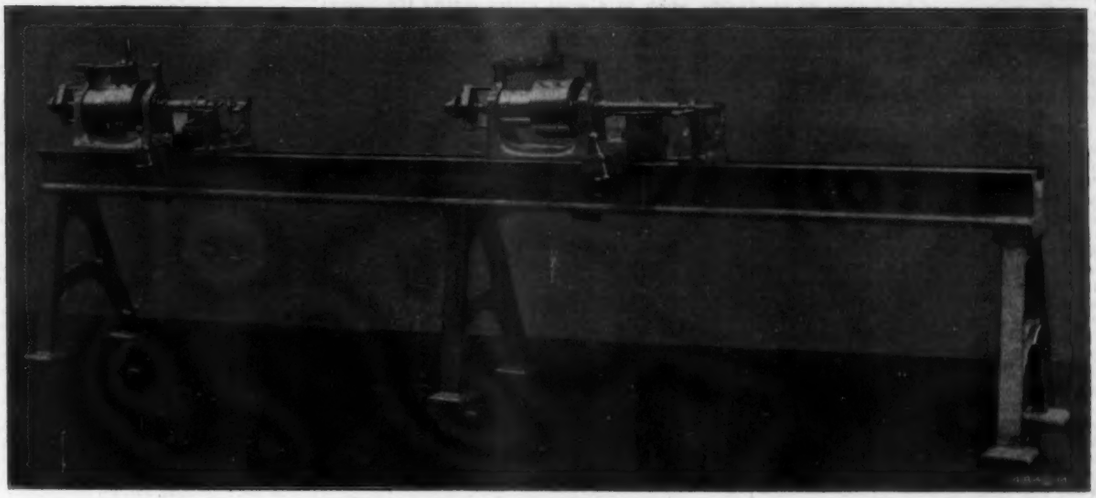


FIG. 10. MACHINE FOR TRIMMING BEFORE THE HEADING OPERATION.

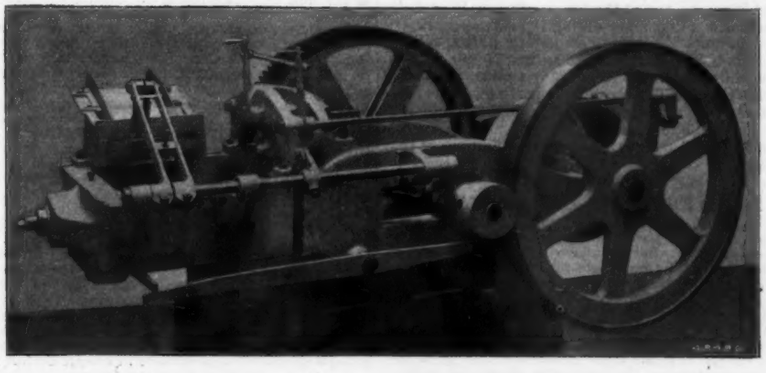


FIG. 11. HORIZONTAL TAPERING MACHINE.

chemical composition, has been used for a high-speed cutting material :—

Cobalt	52.03
Chromium	29.36
Tungsten	12.71
Iron	5.35
Nickel	0.45
Manganese	0.24
Silicon	0.09

The material is very brittle, so that tools provided with it must be well supported close to the cutting edge. It is produced in short cast bars of a suitable section to be ground for the tools requiring it. These special cutting edges may be brazed or electrically welded to shanks of carbon steel, and can be used until repeated grinding renders the special edge extremely thin.

The chief sources of the world's supply of chromite, from which the bulk of the metallic chromium and chromium salts are obtained at present, are the important deposits in New Caledonia, where it was first discovered in 1874, and in European and Asiatic Turkey. New Caledonia is a French colony in the South Pacific Ocean, lying to the south-west of the New Hebrides and about half-way between the Australian coast and the Fiji Islands. It is a long narrow island of volcanic origin and material, rising from a deep trough in the ocean, with soundings of over 2,000 fathoms both to the north and south. It is remarkable that the volcanic rocks of which the island is built up contain chromite, nickel and cobalt in extensive workable deposits; all three being of exceptional occurrence elsewhere in quantity, more especially nickel and chromite. The ores are exported from New Caledonia to the annual value of about 250,000*l*. The main deposits have been found in the southern portion of the island. The ore occurs in two forms—rich, soft and readily broken in ferruginous clay, and as veins and included masses in hard serpentine rock. The former is the more largely worked. From the largest workings about 4,000 tons of ore are obtained per month, containing up to 67 per cent. of chromium sesquioxide. With one exception all the workings are open cuts; the only chrome ore mine in the island worked below the surface is one to the south of Noumea; this ore only contains 30 to 40 per cent. of chromium sesquioxide.

The chrome ore shipped from New Caledonia has varied in quantity between large limits, and very recent figures are not at hand :—

1900	10,470 tons
1901	17,450 ,,
1902	10,380 ,,
1903	21,130 ,,
1904	43,190 ,,
1905	51,370 ,,
1906	57,360 ,,
1907	25,370 ,,
1908	46,480 ,,
1909	32,130 ,,
1910	28,240 ,,
1911	33,000 ,,
1912	40,200 ,,

The production of chrome ore in Asiatic Turkey has been carried on upon an extensive scale and for a considerable period. The country around Brousa in the province of Aidin contains important deposits, others are found near Makri and at Harmaryack. For a considerable period these regions supplied almost the entire requirements of the world. More recently the difficulties and expense of transport from the interior to the coast have compelled the greater number of chrome mine owners to shut down their works, as they found it impossible to compete against the cheaper chrome ores obtained from New Caledonia and Rhodesia. Recent exports of chrome ore have been low grade, obtained from the leavings of former concession-holders. Many large and rich masses of chrome ore are known to exist, but their situation renders it impossible to work them and to transport the ore at a profit abroad. Capital judiciously laid out to provide transport facilities may enable this district, when peace has been restored, again to become an exporter on a large scale. The ores are generally soft and contain 52 per cent. of chromium sesquioxide. Chromiferous iron ores have been found in Western Australia.

The volcanic rocks of India contain chromite in many localities, but no very extensive output has been made. In Africa large quantities of chrome ore have been mined in Rhodesia, and numerous outcrops have been noted in the Transvaal of low-grade ore, containing about 35 per cent. of chromium sesquioxide. As regards the ore in Europe, Great Britain may be classed as a non-producer, although outcrops occur in a few outlying districts of Scotland; two years ago 100 tons were produced, but during 1913 there was no output. Both chromiferous iron ores and chrome ores of the usual type are found in Greece, around Pharsala, Thessaly, where they are mined in considerable quantities; the whole output is exported. These chromiferous iron ores contain approximately 50 per cent of iron and 2.5 per cent. of chromium; the chromite ores range from 30 to 50 per cent. of chromium sesquioxide. These Greek chrome ores yield potassium chromate, lead chromate and others; they are brilliantly coloured and can be used for calico printing. The serpentine rocks of Central Europe also contain chromite, generally low-grade, but in great quantity. There are many chromite mines in the Ural district.

The mining of chromite in the United States is an industry of relatively small importance, essentially due to the somewhat limited extent of the deposits. The average annual output since 1880 has been approximately only 1,300 tons. Chromite has been found in many States of North America, where it was first discovered some 90 years ago, notably in Massachusetts, Pennsylvania, Maryland, North Carolina, Wyoming and California, but several of the deposits have been exhausted. The ore was discovered in California about 40 years ago, but there was no output until 1880; since then nearly the whole of the chromite produced in the United States has come from that State. Important deposits have been quite recently discovered south-west of the Californian town of Yreka, the ore assaying 40 to 45 per cent. of chrome; they are being opened out, and a heavy output is expected from that district. The older deposits occur in San Luis Obispo, Alameda, Placer, and Calaveras counties, as well as in Shasta county, from which for several years the main output has been obtained. These Californian outputs consist of a hard black ore mixed with serpentine; there are also hard

black ores containing little or no serpentine, whilst others are more or less disintegrated, soft, grey chromite ores. Through the Panama Canal these Californian ores will be sent, subject to very low charges, to the ironworks of the Atlantic Coast States.

Very recently chromite has been also discovered in Columbia, where two mines have been opened out and extensive arrangements are being made for a considerable output. From one of these mines 50 tons daily are now being obtained, and a similar quantity from another mine at Forbestown. This ore is also sent to the coast and is then shipped to plants in the eastern States, where it is worked up. Small quantities of chromite sand have been obtained from the Baltimore district.

Canada has a limited output of chromite: for some years 6,000 to 8,000 tons and more annually were obtained from several districts of Quebec. Deposits also occur in Newfoundland in diorite and serpentine. Chromite associated with platinum has been found in British Columbia, a few miles from the village of Tulameen, but the supply so far has been a limited one. On the Olivine mountain, about 25 miles north of the Columbia, United States boundary, and about 217 miles east of the Pacific coast-line, a very remarkable deposit of chromite ore has been found, also associated with serpentine, in which minute diamonds are embedded, about the size of a pin-head. Some of the North American deposits are in localities from which the freight would render it unprofitable to work them. The ore obtained from the various sources outlined above generally requires some treatment to render it available for the market. It is usually subjected to a process of hand cobbing, or mechanical dressing, the former consisting in breaking down the ore to a suitable size to be hand-picked. When this breaking down is done mechanically some loss is occasioned by the production of dust, so-called "fines." The ore, after being cobbed, is passed over a screen to separate the lumps, and can then be hand-sorted from a revolving table, the final result being a product containing about 50 per cent. of chromium sesquioxide.

THE PRICE OF COAL IN GERMANY.

THERE has been a somewhat protracted struggle going on in Germany between the coal-mining interests and the Government on the prices for coal, coke and other kinds of fuel. The producers have been anxious to raise their quotations, and the authorities have been equally desirous of keeping prices at their present level. After lengthy negotiations in the Ministry for Commerce, in which producers of coal in all districts and of all kinds of coal have taken part, the latter, apparently, have gained the day, a general rise in quotations having been sanctioned and promptly declared. It may be noted in this connection that the Government hardly possesses any strictly legal right to control the prices for coal, saving a veto of the Prussian Crown within the Rhenish-Westphalian Coal Syndicate, against a rise. But during the war a custom has obtained of subjecting quotations to the approval of the Prussian Ministry of Commerce, which in case of need could fall back upon the threat of a decree enforcing maximum prices.

The following rises in the quotations were sanctioned by the Ministry for Commerce and announced by the Rhenish-Westphalian Coal Syndicate and the Upper Silesian Coal Convention as coming into force from January 1 for the first quarter of the new year.

For the Rhenish-Westphalian Coal Syndicate: Coal 2.00 marks per ton; coke, 3.00 marks per ton; and coal briquettes, 3.25 marks per ton, making the total increase since the beginning of the war respectively 5 marks, 5 marks and 5.75 marks.

For the Upper Silesian Coal Convention: 2.00 marks per ton for coal, making the total rise since the beginning of the war 4 marks per ton. For lignite briquettes, central Germany, 1 mark per ton; for all other districts, 1 mark per ton, making the total rise since the war broke out respectively 4.00 marks and 3.00 to 3.25 marks per ton.

The Rhenish-Westphalian Coal Syndicate originally asked for an increase of 3 marks. For lignite briquettes the producers held out for 2 marks per ton, only 1 mark being conceded, the Government holding that in the lignite briquette industry the rise in cost of production was not so serious as in the coal-mining industry, because with the former the manufacturing process was a more important factor in the cost than labour, in addition to which the lignite industry had been able to increase its production during the war and thereby its turnover. This industry, besides, has obtained a chance of somewhat recouping itself by being allowed to abandon the reduction in price for industrial briquettes as compared with briquettes for household purposes, which means a rise in the quotations for briquettes for industrial purposes of several marks.

No limits of prices have been fixed for lignites themselves, partly because the price in this case varies considerably according to quality and partly because the lignite is mostly used in the immediate neighbourhood of the deposits for generating electric energy, in the chemical industry, &c. In Upper Silesia no price limit has been arrived at for coke, the quotations generally being fixed through arrangements between the coke works and the Prussian Crown mines and the chemical works, which to a great extent control the Upper Silesian coke production as far as the private companies are concerned. The heavy rise in the quotation for coal briquettes is accounted for by the material rise in the price of pitch.

The authorities, to begin with, were against any rise in the quotations for fuel, but the coal-mine owners produced such convincing figures as regards the higher cost of production that the authorities had to revise their views. Sixty coal-mining concerns of divergent kinds and magnitude showed that on an average the cost of production had increased as much from the spring to the fall of 1916 as during the whole of the preceding time of the war. Thus the cost of production at a concern with seven large shafts had risen 2.26 marks per ton from the beginning of the war until July 1, 1916, and from that date to October, 1916, 2.08 marks per ton. Another concern, with 17 shafts, showed a rise of 2.21 marks per ton from the beginning of the war to July 1, 1916, and 2.87 marks per ton from that date to November, 1916. Matters varied a good deal for the different mining concerns; one with four shafts had a rise of 3.20 marks per ton in cost of production during the first of the above periods, and only 1.29 mark per ton during the second. At an entirely new concern, still in a stage of development, the corresponding figures were 2.77 marks and 4.11 marks per ton. A similar state prevailed in other coal districts and also in the lignite industry. The same applies to the Crown coal mines; thus at the Crown coal mines in the Saur district the cost of production rose 3.04 marks per ton from October, 1915, to October, 1916; at the Crown mines in Upper Silesia it rose 2.28 marks, and at the Crown mines in Westphalia even 4.93 marks per ton during the same period. In addition there are grants in aid of different kinds amounting to about 1,000,000 marks per month. While the new rise in prices may enable the Crown mines in the Saur district and in Upper Silesia to manage, the Ruhr Crown mines in the Recklinghausen district may also require grants under the new prices on account of the unfavourable working conditions in that locality.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, December 27.

THE clamour for shell steel continues, notwithstanding the talk of peace, which is viewed at different angles on this side, and at bottom meets with very little sympathy among the real thinkers of the country. Large orders were placed during the past week, even in the over-sold condition of every producing interest. It was ascertained to-day that a good deal of material and supplies are urgently wanted, but no efforts have been made to close, though it is probably certain that the week will see more business at the locomotive shops, car builders and mills. France secured promises of satisfactory delivery for 10,000 tons billets, Italy 20,000 tons, and Canada 10,000 tons, which is part of a very large order soon to be placed. The aggressions of Germany are apparently industrialising Russia in the way of transportation. Foreign roads have taken 577 locomotives, the total contracts amounting to 800. Merchant builders have taken additional orders for 11,000 cars. Railroad shop extensions have absorbed orders for 50,000 tons of shapes, but this is only a small proportion of the contemplated requirements. The volume of recent business in bars, plates and shapes amounted to 150,000 tons; the peace talk caused very little more than a ripple in the trade, and the demand for shell steel is as urgent as heretofore. All high-carbon steel is promptly taken up. Additional wire contracts just reported figure up to 30,000 tons for export. Russian and French roads are the largest buyers of locomotives, but there is a demand from India, East Africa, Java and the Belgian Congo. The domestic railway systems are in great urgency of mind to place the largest orders possible for equipment, especially rolling-stock; and next in importance to shell steel, locomotives and plates is the urgency for structural steel for railroads, shipyards, and manufacturing plants. Total inquiries from these three sources this week aggregate 40,000 tons. A great deal of marine work is also appearing, and pig-iron—considering the difficulty of inducing furnaces to accept orders—is rather quiet, though Italy, Scandinavia and Holland managed to secure promises of delivery for some 40,000 tons.

STEEL PRICES.—With reference to the Notice of Modification by the Minister of Munitions of the general permit relating to dealings in metallurgical coke, pig-iron and steel published on page 5 *ante*, the Minister of Munitions now gives notice that the sum of 13*l.* is substituted for the sum of 13*l.* 10*s.* mentioned formerly as the maximum basis price for mild steel diamond pattern chequer plates, ¼-in. thick on plain and over, and the sum of 21*l.* 10*s.* is substituted for the sum of 21*l.* mentioned as the maximum basis price for higher high tensile steel angles, 7 united inches and over.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—The annual return of the coal traffic dealt with at the Humber port gives conclusive evidence of the decline in the export business. The tonnage shipped for the Admiralty and Allied Governments is excluded from any comparison with preceding years, but it is established that the aggregate of 3,290,281 tons sent last year is fully 1,250,000 tons less than the previous year and 2,500,000 tons of a reduction on the 1914 figures. The total is the smallest on record for the past 14 years. The export trade has chiefly suffered, showing an exceptionally large reduction on 1915. France was the largest buyer, with 558,591 tons, or 50 per cent. of the total. Sweden received 170,948 tons, Italy 125,657 tons, Holland 83,297 tons, Norway 15,766 tons, and Denmark 6,968 tons. Only in the case of Italy was a substantial decline not recorded, and in that case the shipments rose nearly 70,000 tons. The list of collieries supplying the port was again headed by the Denaby and Cadeby Main, with 540,006 tons.

South Yorkshire Coal Trade.—Pits are now working much more consistently, despite the recent heavy fall of snow all over the country during the last few days. With supplies coming to hand more readily the market has a better tone, though it is hardly correct to state there is any freedom of choice. Munition works, railways, and other important industrial users are requiring large deliveries of steam coal, but the situation does not permit them to replenish the much-depleted stocks. Smaller sorts are easier. House coal is again meeting a brisk demand. Gas coals are also wanted in heavy amounts. Cokes remain at their usual top level. The export trade presents few features of interest. Quotations:—Best branch hand-picked, 20*s.* 6*d.* to 21*s.* 6*d.*; Barnsley best Silkstone, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire best brights, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire house, 17*s.* to 18*s.*; best large nuts, 16*s.* 6*d.* to 17*s.* 6*d.*; small nuts, 15*s.* 6*d.* to 16*s.* 6*d.*; Yorkshire hards, 16*s.* 6*d.* to 17*s.* 6*d.*; Derbyshire hards, 16*s.* to 17*s.*; best slacks, 12*s.* to 13*s.*; seconds, 10*s.* 6*d.* to 11*s.* 6*d.*; small, 7*s.* 6*d.* to 8*s.* 6*d.* per ton.

Iron and Steel.—Business is now again in full swing after the holidays, and this is reflected in the condition of the iron and steel markets. Steel for general trade purposes, outside direct munition work, is a scarce commodity, and the probability is that it will become even more so when the additional works get into thorough running order. Steel furnaces are swallowing up all available hematites, and if these could be speedily augmented the tightness of the position might be relieved. Foundry iron makers find the market a shade firmer. Hoop and merchant iron meets a heavier demand than there is tonnage available, particularly in the case of the latter brand. Quite a brisk tone characterises the scrap-metal trade. It may be stated here that the revision of the maximum prices for steel scrap, and the inclusion of best qualities guaranteed to analysis, meets with approval in Sheffield circles. The steel trade generally is in a state of flux. Manufacturers are being apprised of the Government requirements in their particular lines. New contracts are being arranged in many instances. Some inquiries are for 5,000 high-speed twist and twisted drills, 30,000 or 40,000 carbon twist drills, 3,000 saws, 3,000 scrapers and scoops, 4,000 sledge hammers, 2,000 shovels, 100 anvils, 8,000 boring and jumping bars, 500 farriers' hammers. The tool trade is inundated with orders, and one leading firm informs us that it is at present in arrears on last year's orders to the extent of 100,000 twist drills of all classes. Tramway work continues good. Sheffield corporation is carrying out extensive repairs and renewals, and among the orders placed on its behalf is one for 12 sets of manganese steel points. A Sheffield firm has received a contract from the Johannesburg city council for tramway steel supplies. An important deputation, we are informed, is this week to wait upon the Minister of Munitions in London on behalf of the cutlery, plate and silver trades. It will lay before Dr. Addison the serious nature of the embargo upon the use of copper and open-hearth steel in these several industries, and will endeavour to induce him to allow manufacturers a moderate quantity of each metal in the national interests. Plate makers would be satisfied in some degree if they were allowed the use of a certain class of scrap alloy metal which is quite plentiful. The whole three trades are resolved that if the home trade must go, they will make a bold bid to keep the foreign and Colonial custom. But this depends upon the reply of the Ministry. From oversea indents have come to hand for tools, saws, files, knives, springs, cutlery and steel.

Sheffield Trade Matters.—The local branches of the Poldi Steel Company, of Austria, and of Bohler Brothers, of Berlin and Vienna, have been wound up and disposed of under the "Trading with the Enemy Act." The latter undertaking has been acquired by Mr. Geo. H. Cook, who, until lately, was the manager of the old concern. He intends to trade as Geo. H. Cook and Co. at the same address. The works will be known in the future as the "Uniformity Works."

Big Electric Power Scheme.—The Lord Mayor of Sheffield, speaking last night (Tuesday) at a public meeting at which it was decided to proceed with the corporation Bill to acquire powers for the new electricity undertaking on the Blackburn Meadows estate, stated that the city council had been informed by the leading manufacturers in Sheffield that they were greatly in favour of the ambitious scheme, for they had orders for no less than 10 or 12 years ahead. It is interesting to note that the scheme is really an after-war undertaking. It will extend over 35 acres and cost over 1,500,000*l.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—Although the steel works in the West of Scotland were supposed to make a fresh start again after the holiday on Thursday last, various circumstances, notably the requisite overhauling of machinery and plant, prevented a general resumption of business until Monday of this week. Consequently, viewed from an industrial standpoint, the first week of the year was fairly quiet. Such conditions, however, will not endure for any appreciable length of time, as the requirements of our own and the Allied Governments are heavier than ever, and manufacturers and workers alike must strain every nerve to increase the output in order to meet the demand for war material of every description. In consequence, every mill will require to be run to its fullest capacity, and the entire energies of all the available labour to be devoted to the turning out of the various contracts with the utmost possible speed.

Scotch Pig-Iron Trade.—The conditions of ceaseless activity, which have been so marked a feature of the Scotch pig-iron trade since very shortly after the outbreak of war, show no prospect of any immediate diminution, and the New Year has been inaugurated with this important industry brisker and more flourishing than perhaps ever before. Everything possible is being done to increase production; yet, despite this, unavoidable delay is constantly occurring, and makers have increasing difficulty in keeping pace with the demands of consumers. With the Government limitation of the export both of hematite and foundry iron it was confidently expected that better supplies would be available, but so far little change is to be observed and the pressure is still very keen, and likely to remain so for some time to come, as the demands of the steel works, both for hematite and foundry iron, are insatiable. Prices remain much on the same level as during the closing weeks of the year.

Transport Workers' Battalion at Glasgow Docks.—Quite a good start has been made at Glasgow Docks, where, at the urgent request of the Port and Transit Executive Committee, considerable numbers of the Transport Workers' Battalion are being employed as occasion demands, principally on the discharge of ore, which is certainly the most pressing need of the moment. About 150 of the men are at present engaged on this work, but their services are only enlisted when there is a shortage of local labour, there being no desire to oust the ordinary dock labourer, but only to speed up the work, which is of such great importance.

Scotch Steel Trade.—With the additional stiffening of the Government restrictions regarding mercantile work of any description, which has just taken place, steel makers who have booked orders for other than war work are meantime placed in rather a tight corner. Even with this curtailment it is impossible to meet the present demand. Home prices being fixed, those for export are merely nominal just now, boiler plates being quoted at about 15*l.* 15*s.* to 15*l.* 17*s.* 6*d.* per ton; ship plates, 14*l.* 12*s.* 6*d.* to 14*l.* 17*s.* 6*d.*; and angles, about 14*l.* 15*s.*

Malleable Iron Trade.—Malleable iron-makers continue to report particularly brisk business, with the pressure for delivery undiminished. While Government naturally has first claim on the entire output, it is increasingly obvious that, with the means at command, there is not the slightest possibility of any ordinary mercantile work being undertaken at the present. For "Crown" bars 14*l.* 12*s.* 6*d.* is quoted, and it seems as if this rate might be maintained for some little time.

"AIR."—The issue for January of this periodical, the official organ of the Aeronautical Institute of Great Britain, among information of general interest, gives technical articles on the design and characteristics of types of aerial propellers, and on the stagger and camber of biplane wings.

PERSONAL.—Mr. Fredk. R. Archer, engineers' tool manufacturer, 5, Farringdon-road, E.C., informs us that he has amalgamated his business with that of Messrs. Lehmann Bros., Hampshire Works, Station-road, Walthamstow, N.E., manufacturers of taps and dies and screwing tools generally. The amalgamated business will be carried on at the above address, and at Hampshire Works, Station-road, Walthamstow, N.E.

THE PANAMA CANAL.—The channel in the cut, says the *Panama Canal Record*, is in better condition now than ever before. The central cut through which the vessels pass, known as the sailing channel, has a minimum depth of 33 ft., and the least width of a channel of 30 ft. depth is 180 ft. This is opposite the rock known as "Gibraltar," at the foot of the East Culebra slide. This rock extends into the channel about 110 ft. from the prism line, for a distance of about 220 ft. along the axis of the canal, from station 1792 to 1794. At other parts, between the Culebra slide and at Cucaracha slide, the channel has been dredged to at least 30 ft. for the full width of 300 ft. between the prism lines. The dredgers Corozal and Paraiso are at work in the slide area. They are working close to "Gibraltar," removing the rock itself and cutting-in behind it to prevent its being pushed forward. A number of drills are engaged every day, including Sundays, on the work of drilling and blasting the rock for the dredgers to remove it. It has been considerably reduced in size, and now extends only about 30 ft. above the surface of the water in the cut. The smaller dredgers have been withdrawn, because only a few can work to advantage in the area to which dredging is now confined, and the large dredgers can operate less expensively.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Though the holidays are now finished traders do not show a great deal of disposition to do business. At the same time consumers of Cleveland pig-iron, both here and in Scotland, are in the market to buy, but their operations are checked by the fact that allocations for January have already been made. As, however, some of the makers have already executed the orders allotted to them for this month, there is reasonable ground for belief that permission will be granted to put more business through. A small sale to Scandinavia is understood to have been made, but licences for shipment to neutral countries are very difficult to obtain. For home consumption No. 3 Cleveland pig, No. 4 foundry, and No. 4 forge all stand at 87*s.* 6*d.*, and No. 1 is 91*s.* 6*d.*; whilst for despatch to our Allies No. 3 is fully 98*s.*; No. 4 foundry, 96*s.* 6*d.*; No. 4 forge, 95*s.* 6*d.*; and No. 1, 102*s.* 6*d.*; and for shipment to neutrals No. 3 is 105*s.* and upward, and No. 1 quite 110*s.*

Hematite Iron.—So far as hematite iron is concerned all home needs are being satisfied without difficulty, but permits for export of new business are not forthcoming, as considerable parcels are overdue for shipment on contracts made some time ago. Mixed numbers are 122*s.* 6*d.* for home use, 137*s.* 6*d.* for shipment to France, and 142*s.* 6*d.* for export to Italy.

Stock and Shipments of Pig-Iron.—The stock of Cleveland pig-iron in the public warrant stores stands at 3,598 tons, 140 tons having been withdrawn so far this month. Shipments of pig-iron from the Tees so far this month are officially returned at 5,124 tons, as compared with 11,260 tons to the same date last month, and 5,962 tons for the corresponding part of January last year.

Blastfurnacemen's Wages again Advanced.—The average net selling price of No. 3 Cleveland pig-iron for the three months ended December 31 last has been certified at 89*s.* 0.17d. per ton, as compared with 87*s.* 11.31d. per ton for the previous three months. There was thus an advance in price during the last quarter of 1916 of 1*s.* 0.86*d.* per ton, and under sliding-scale arrangements blastfurnacemen's wages in the North-East district are this quarter advanced by 1.50 (1½) per cent., raising wages from 69.75 (69¾) per cent. above the standard to 71.25 (71¼) per cent. above the standard.

Coke.—There is a large and growing demand for coke for local use, and fixed maximum prices are firmly held. Average blast-furnace kinds continue to realise 28*s.* at the ovens, and up to 30*s.* 6*d.* at the ovens is still named for qualities low in phosphorus.

Foreign Ore.—Good supplies of foreign ore are coming forward. So far this month unloadings at the port of Middlesbrough have been satisfactory.

Manufactured Iron and Steel.—Little new is ascertainable concerning the various branches of the finished iron and steel industries. Manufacturers have a great deal of work on hand, and they report steady increase in the production of mercantile shipbuilding material, acceleration in shipbuilding being responsible for considerable new development. Most of the finished iron and steel works are in full swing again, and have effected much-needed repairs and renewals to plant during the holidays. Quotations, all round, are very strong. The following are among the principal market rates for home use:—Common iron bars, 13*l.* 15*s.*; best bars, 14*l.* 2*s.* 6*d.*; double best bars, 14*l.* 10*s.*; treble best bars, 14*l.* 17*s.* 6*d.*; iron ship plates, 13*l.* 10*s.* to 14*l.* 10*s.*; iron ship angles, 13*l.* 15*s.*; iron ship rivets, 17*l.* 10*s.* to 18*l.* 10*s.*; packing iron and steel (parallel), 12*l.*; packing iron and steel (tapered), 14*l.* 5*s.*; steel bars (no test), 14*l.* 10*s.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel ship rivets, 19*l.* to 20*l.*; steel boiler plates, 12*l.* 10*s.*; steel joists, 11*l.* 2*s.* 6*d.*; steel strip, 17*l.*; steel hoops, 17*l.* 10*s.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*

Ironstone Miners' Wages Advanced.—The Cleveland ironstone mine-owners met a deputation of miners at Middlesbrough this week to discuss the question of wages. Sir Hugh Bell, Bart., presided over the conference. It was agreed that wages at the mines be increased by 2½ per cent. from the 22nd inst.

THE TRADE OF NEW SOUTH WALES.—The oversea imports during September were valued at 3,085,089*l.*, and show an increase of 598,940*l.*, or 24.1 per cent., as compared with the corresponding month of 1915. The total for three months was 9,165,685*l.*, an increase of 380,329*l.*, or 4.3 per cent., in comparison with the figures for 1915. The oversea exports of merchandise during September amounted to 2,572,988*l.*, being an increase of 489,107*l.*, or 23.4 per cent., as compared with the corresponding month of 1915.

THE LATE DR. EMIL FREY.—We regret to note the sudden death, a few days before Christmas, of Dr. Emil Frey, director of the famous hydro-electric power plant at Rheinfelden, on the Swiss side of the Rhine, a little to the east of Basle. Frey was born in 1861 in the Canton of Aargau, and became a member of the administration of his Canton in 1894, after having studied law at the universities of Strassburg, Heidelberg and Munich. Within a year of this appointment he accepted the directorship of the new Rheinfelden works. When electric power supply to both Swiss and German works in the neighbourhood was introduced, knotty legal problems had to be solved. Frey's sound judgment was appreciated in both countries, and he was later often consulted on similar international questions.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Business in the coal trade remained slow, mainly owing to the uncertainty which rules in regard to forthcoming tonnage. Best Admiralty large and best seconds continued to be nominal. Other quotations for steam coal were as follow:—Secondary qualities, 30*s.* to 31*s.*; Black Veins, 30*s.* to 31*s.*; Western Valleys, 19*s.* to 30*s.*; Eastern Valleys, 27*s.* to 29*s.*; best bunker smalls, 19*s.* to 20*s.*; cargo smalls, 12*s.* to 18*s.* In bituminous coal, best households, at pit, made 25*s.* 6*d.* to 26*s.* 6*d.*; No. 3 Rhondda large, 28*s.* to 30*s.*; No. 2 Rhondda large, 25*s.* to 27*s.*, and smalls, 21*s.* to 22*s.* Patent fuel was quoted 35*s.* to 37*s.* For export, special foundry coke made 62*s.* 6*d.* to 65*s.*; good foundry coke, 57*s.* 6*d.* to 60*s.*, and furnace coke, 47*s.* 6*d.* to 52*s.* 6*d.* Pitwood, ex-ship, made 53*s.* 6*d.* to 54*s.* 6*d.*

Western Trade Matters.—Mr. J. W. Beynon was elected chairman of Fernhill Collieries, Limited, at a meeting of the board of directors held on the 9th inst. Mr. Beynon replaces Lord Rhondda, who has resigned from the board.—The directors of the Mount Stuart Dry Docks, Limited, have declared an interim dividend of 3 per cent. on the preferred ordinary shares and a dividend of also 3 per cent. on the deferred ordinary shares.

THE ORGANISATION OF TRADES.—It is announced that on Thursday next, the 18th inst., at the London School of Economics (University of London), Clare Market, Portugal-street, Kingsway, W.C., Mr. Ernest J. P. Benn will deliver a lecture on "The Organisation of Trades." The chair will be occupied by Sir William M'Cormick, M.A., LL.D., the chairman of the Committee of the Advisory Council for Scientific and Industrial Research.

COAL MINING IN ICELAND.—There seems every prospect of rational coal mining being possible in Iceland, and preparatory work is being pushed ahead with considerable energy. For this purpose a Danish-Icelandish Coal Mining Company has been formed, with a capital of 350,000 kr., privately subscribed, which will be greatly increased when deemed necessary. A Swedish expert has examined and reported upon the Icelandish coal deposits; he estimated them to contain some 180,000,000 tons. The quality is said to be considerably better than hitherto supposed. The coal is reported to be fully equal to Scotch coal, and even if, on account of its large percentage of ash, it is unsuited for steamship boilers, a good market for it will be found for use for domestic purposes and power stations.

NORWEGIAN SHIPBUILDING CONTRACTS IN THE UNITED STATES.—The extensive orders for tonnage placed with American yards by Norwegian owners have for some time attracted much attention, both in the United States and in Europe. Not only has the Norwegian demand for new vessels been in excess, at least recently, of the will or ability on the part of the American shipbuilders to comply with it, but some apprehension is now being felt at so much tonnage actually leaving the country. The latest phase in this connection is an American endeavour to purchase back the sale contracts from the Norwegian buyers. Some substantial premiums had been offered before the recent peace manœuvres set in, but negotiations were dropped temporarily. Now that the attitude of the Allies towards these peace endeavours has become sufficiently manifest, the movement has again taken root, and the last few days have witnessed several handsome offers from the other side to secure the Norwegian contracts. The Norwegian owners, however, do not appear much disposed to part with their coveted contracts, as they view the future of shipping, at least for a considerable time to come, in a favourable light.

PICTURES OF WAR WORK.—Mr. Joseph Pennell was authorised by the Government to make a series of drawings and lithographs of munition works, and these have now been reproduced in a volume published by Mr. William Heinemann, of 21, Bedford-street, London, W.C., and by Messrs. J. B. Lippincott Company, of Philadelphia, U.S.A., at the price of 6*s.* net. In an introduction, Mr. H. G. Wells says, "It has been wise of Mr. Pennell to make his pictures of modern warfare not upon the battlefield but among the huge industrial apparatus that is thrusting up behind and thrusting up through the war of the gentlemen in spurs. He gives us the splendours and immensities of forge and gun pit, furnace and mine-shaft. He shows you how great they are and how terrible." The volume contains 51 plates, and, commencing with the iron mine, follows more or less regularly the manufacture of shells, armour plates and guns. Engineers will be pleased to see their work in the great war acknowledged in this fashion, but they will be surprised to learn how different is the appearance their works and machines present to an artist from that which they themselves see. The artist is occupied with the general effect, the contrast of light and shade, the evidence of power, and the sense of complexity, but apparently he has no regard for detail. The engineer, on the other hand, cares little for these things. He is interested to know if the arrangement is economical, if the lighting is uniform, and the plant suitable for its purpose. He doubts whether art has any right of entry in a works. Nevertheless, if Mr. Pennell can make the public realise more clearly how immense and how difficult have been the tasks cheerfully and successfully undertaken by engineers since the war commenced, they will not quarrel with him if his pictures do not clearly differentiate between a flat bar and an angle iron, and if smoke seems to play in them the same part as charity is supposed to do in social life.

CARTRIDGE-CASE MAKING MACHINERY.

CONSTRUCTED BY MESSRS. GREENWOOD AND BATLEY, LIMITED, ENGINEERS, LEEDS.

(*For Description, see Page* 30.)

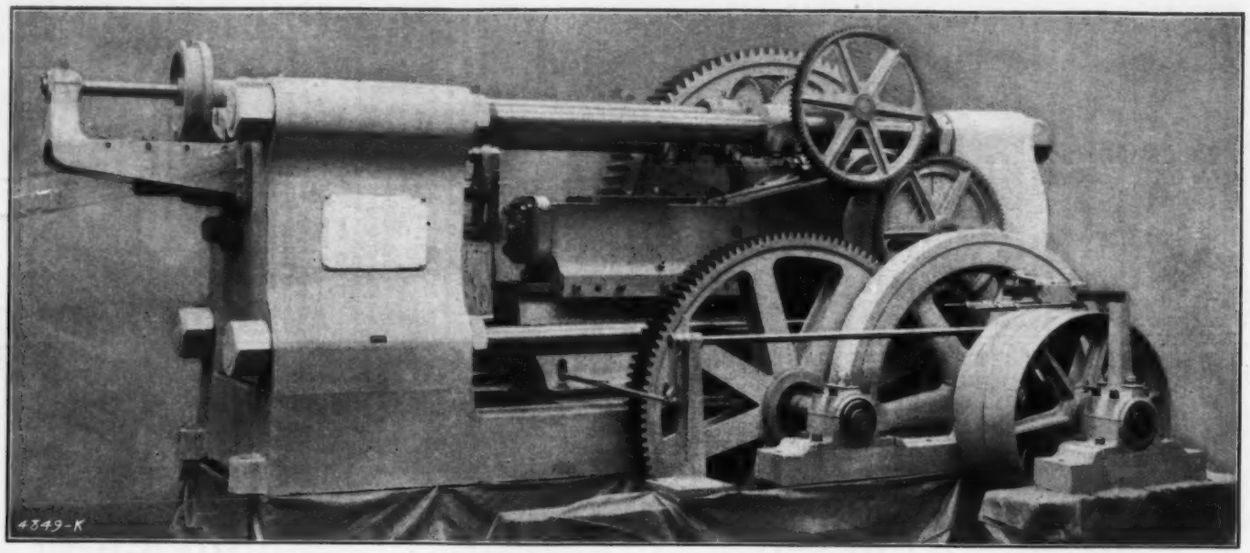


FIG. 12. HEADING MACHINE.

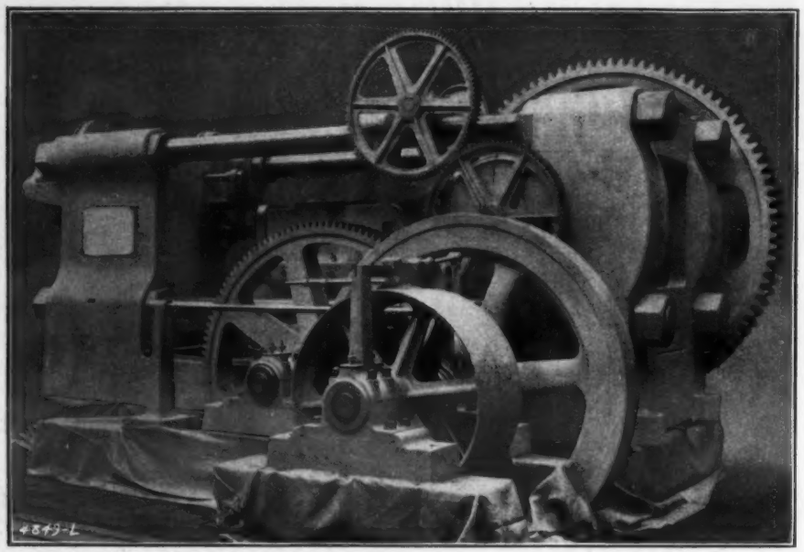


FIG. 13. HEADING MACHINE.

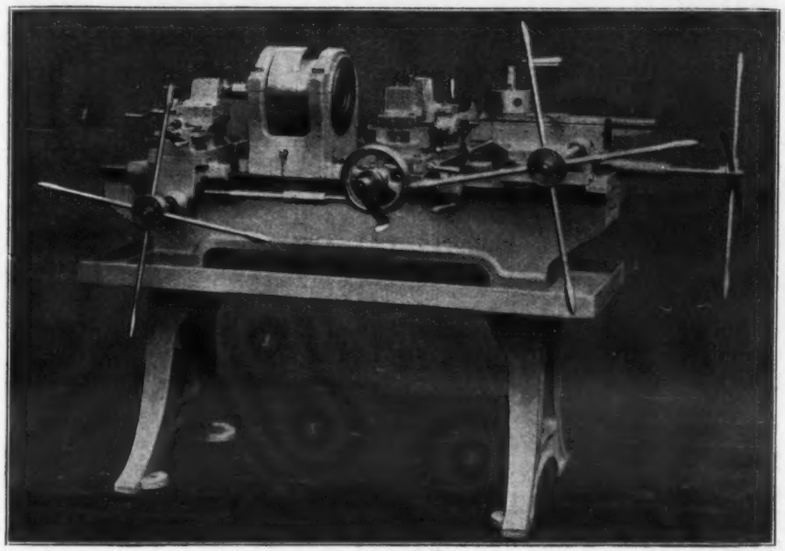


FIG. 14. LATHE FOR HEAD TURNING AND CUTTING TO LENGTH.

CARTRIDGE-CASE MA

CONSTRUCTED BY MESSRS. GREENWOOD & BA

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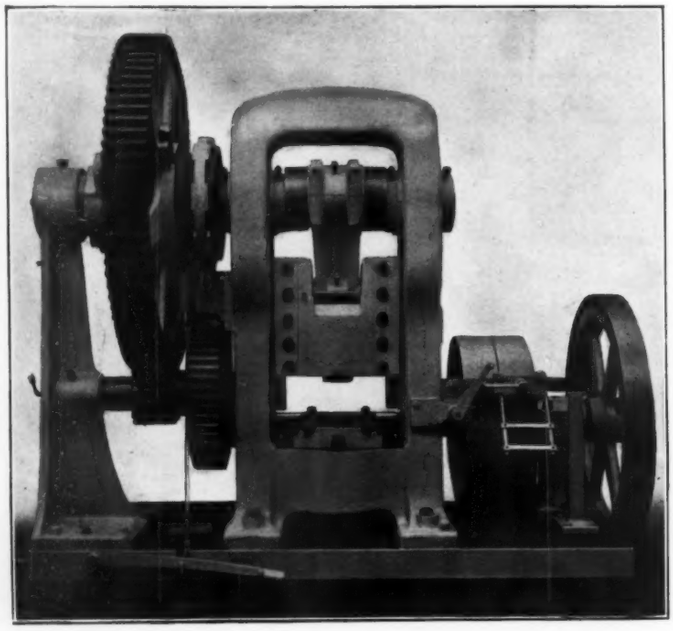

FIG. 1. MACHINE FOR CUTTING OUT THE BLANKS.

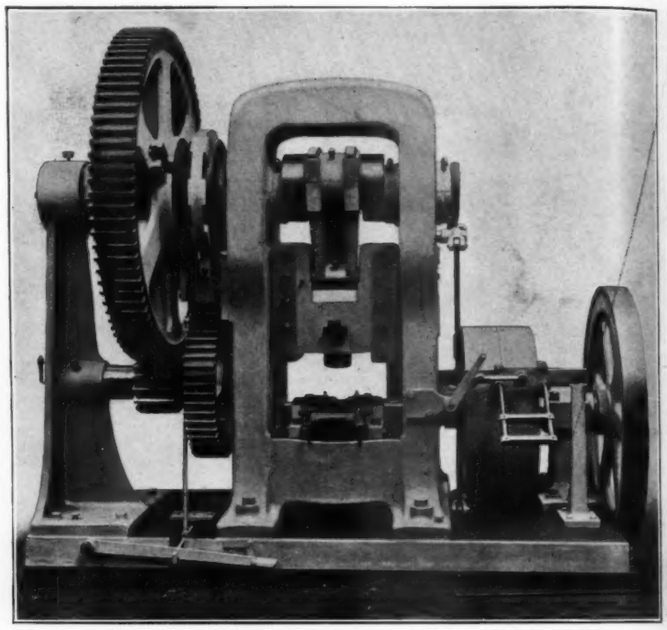

FIG. 2. MACHINE FOR FIRST INDENTING THE BLANK.

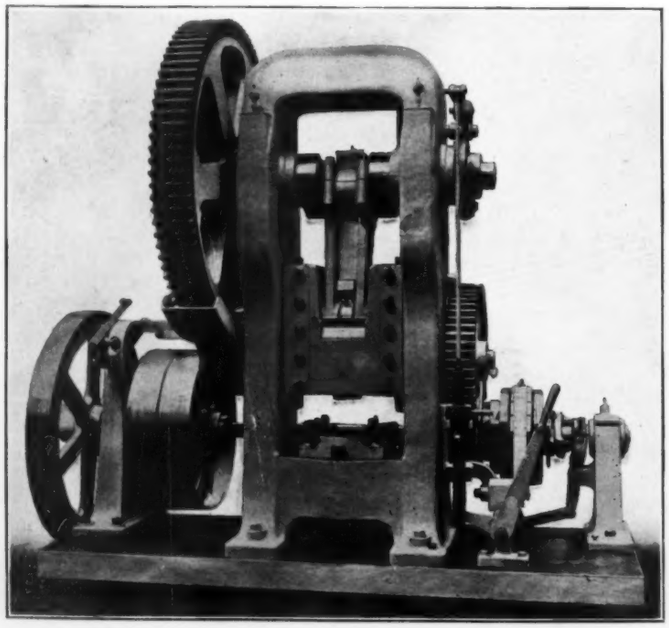

FIG. 5. DOUBLE-GEARED VERTICAL DRAWING MACHINE.

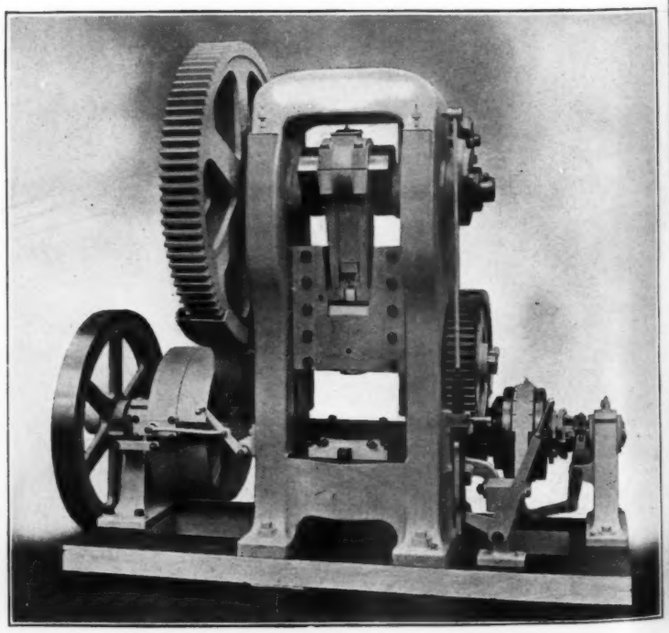

FIG. 6. DOUBLE-GEARED VERTICAL DRAWING MACHINE.

SE KING MACHINERY.

ENWOOD BATLEY, LIMITED, ENGINEERS, LEEDS.

r Descri ee Page 30.)

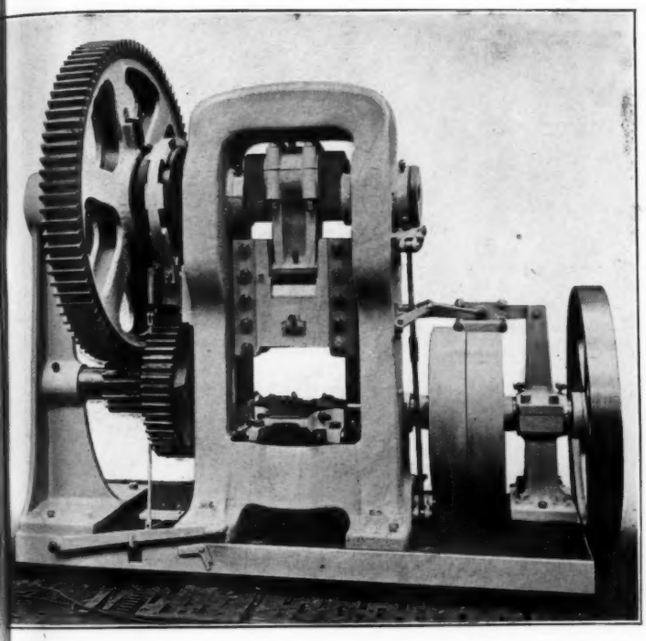

Fig. 3. Machine for First Indenting the Blank.

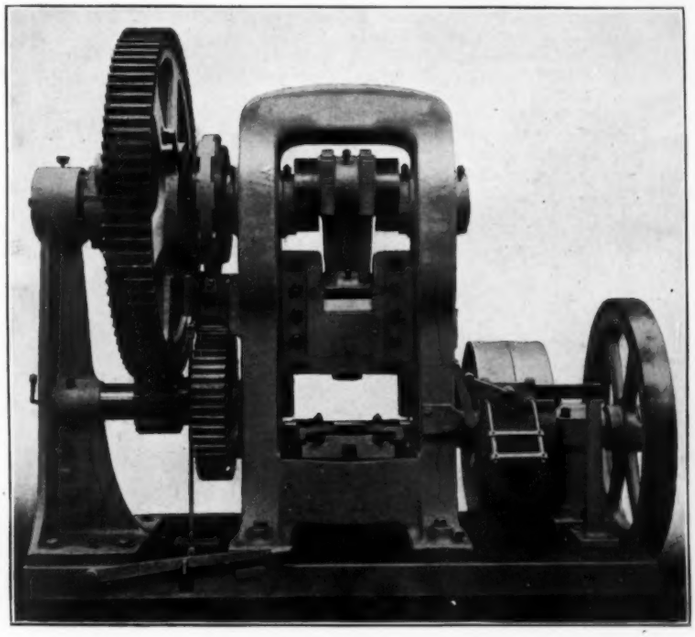

Fig. 4. Machine for Forming the Cup.

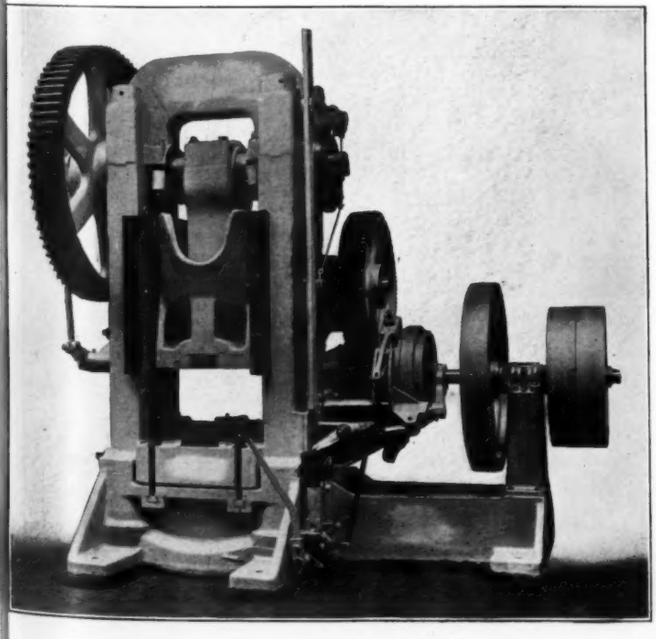

Fig. 7. Vertical Indenting Machine.

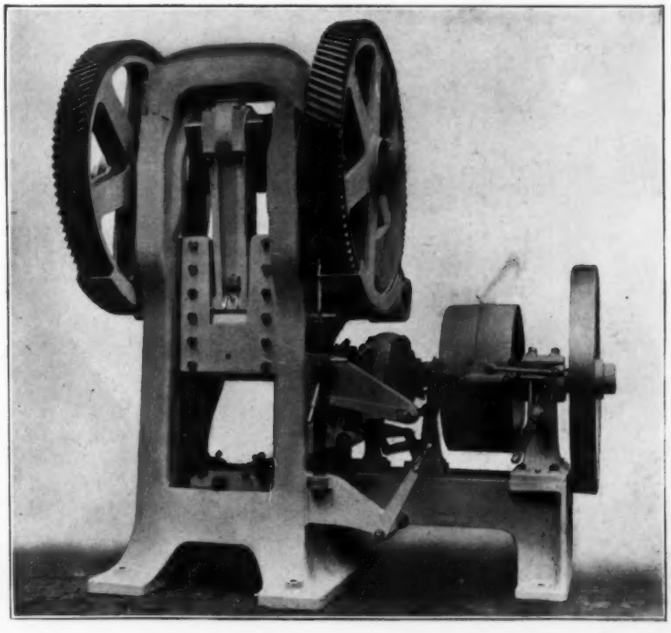

Fig. 8. Vertical Drawing Machine.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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NOTICES OF MEETINGS.

THE ENGLISH CERAMIC SOCIETY.—Saturday, January 13, at 7 p.m., at the Central Schools of Science and Technology. A paper will be read by Mr. J. B. Stobbs, entitled "The Clays and Marls of North Staffordshire."

THE ILLUMINATING ENGINEERING SOCIETY. — Tuesday, January 16, at 5 p.m., at the House of the Royal Society of Arts, John Street, Adelphi, London, when a discussion on "'The Lumen' as a Measure of Illuminating Power" will be opened by Professor J. T. Morris.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, January 16, at 8 p.m., at the House of the Royal Society of Arts, John Street, Adelphi, W.C. The following paper will be read:—"The Occurrence of Petroleum in England," by Mr. William Forbes-Leslie, M.B., F.G.S. The chair will be taken by the President, Professor John Cadman, C.M.G., D.Sc., M.Inst.C.E.

THE INSTITUTION OF ELECTRICAL ENGINEERS: BIRMINGHAM LOCAL SECTION.—Wednesday, January 17, at 7 p.m., at the University, Edmund Street, when Mr. F. Gill and Mr. W. W. Cook will read their paper, entitled "Principles Involved in Computing the Depreciation of Plant."

THE ROYAL METEOROLOGICAL SOCIETY. — Wednesday, January 17, at 5 p.m., at Caxton Hall, Victoria Street, Westminster. Business:—1. Ordinary meeting for the election of new Fellows. 2. Annual general meeting at 5.15 p.m. 3. Report of the Council for 1916. 4. Election of the Council for 1917. 5. Address on "The Winds of North Africa," by Major H. G. Lyons, F.R.S., President.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, January 19, at 5.30 p.m. A discourse will be delivered by Professor Sir James Dewar, M.A., LL.D., D.Sc., F.R.S., M.R.I. The subject is "Soap Bubbles of Long Duration." Afternoon lectures next week at 3 p.m. Tuesday, January 16. Professor Charles S. Sherrington, M.D., LL.D., D.Sc., F.R.S., Fullerian Professor of Physiology, R.I., on "The Old Brain and the New Brain, and their Meaning" (Lecture I). Thursday, January 18. Professor Sir Walter Raleigh, M.A., Professor of English Literature, Oxford, on "The Strength and Weakness of Romantic Poetry" (Lecture I). Saturday, January 20, Mr. Arthur R. Hinks, M.A., F.R.S., on "The Lakes and Mountains of Central Africa" (Lecture I).

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, January 19, at 6 p.m., at the Institution of Civil Engineers. Paper to be read and discussed:—"The Manufacture of Gauges at the London County Council Paddington Technical Institute," by Mr. A. G. Cooke, M.A., Mr. W. J. Gow, and Mr. W. G. Tunnicliffe, Associate Member.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, JANUARY 12, 1917.

THE ANOMALY IN SUPERHEAT CORRECTIONS.

THE rapid strides by which the design of electrical machinery was brought to its present stage of perfection is generally, and no doubt rightly, attributed to the relative ease with which theory could be applied to practice, and much of the equally striking development of the steam turbine is to be credited to a similar cause. In both cases the main difficulties have been practical rather than theoretical in character, but at the same time there was a much larger gap between theoretical and applied thermo-dynamics than existed between the electricity of the laboratory and class-room and that of the power station. Unexpected anomalies were found, for example, in the behaviour of steam discharged from nozzles, since in certain cases the weight passed was proved to exceed the maximum possible on the then accepted theory of the phenomena. This difficulty was only cleared up three or four years ago, by the discovery that the steam was in a supersaturated condition as it passed the throat of the nozzle.

A still outstanding anomaly is to be found in the fact, on which all turbine builders are agreed, that the gain due to the use of superheat is very substantially in excess of what would be anticipated from the theory usually accepted. Of course, neither of these anomalies have had any material effect in retarding the development of the steam turbine. Certain experimental coefficients have to be introduced in any case, in order to pass from theoretical to practical thermo-dynamics, and by suitably choosing these the discrepancies between theory and practice can be rendered innocuous. Such a condition of affairs cannot, however, be considered as wholly satisfactory, since most of us are not content to merely observe and record sequences of events, but have an instinctive desire to fit all natural phenomena into a theoretical framework, one advantage of which is that it becomes no longer necessary to memorise individual results, but merely to learn the general theory from which all possible results should be capable of being deduced. Attempts have accordingly been made to find some theoretical basis for the observed anomalies in superheat corrections. Part of them are due to the use of steam tables based on the erroneous experiments of Knoblauch and Jakob, but only a small proportion of the discrepancy can thus be accounted for. The usual explanation put forward is that wet steam meets with a much higher frictional resistance in flowing through the blading than does dry steam. This view is, however, incompatible with experimental observations on fluid friction. Professor C. H. Lees, F.R.S., has shown* that the whole of the best experimental results on the head lost in the turbulent flow of fluids through pipes can be represented by a single formula, which applies equally whether the fluid be air or water, and that at high speeds the effect of differences of viscosity are relatively small. Still earlier, Osborne Reynolds† had arrived at a similar conclusion, which he expressed as follows:—"When the motion of a fluid is such that the resistance is as the square of the velocity the magnitude of this resistance is sensibly quite independent of the character of the fluid in all respects save that of density." In other words, if the velocity of motion be sufficiently high for the flow of the more viscous fluid to be highly turbulent, the head lost in a given length of pipe will be much the same if one fluid be treacle and the other water. These considerations show the inadequacy of the explanation usually offered for the apparent abnormally high efficiency observed with superheated steams. Another solution is accordingly required.

A fundamental theorem in thermo-dynamics established by Carnot is that the efficiency of a reversible heat engine working between two stated temperatures depends solely on these two temperatures, and is quite independent of the character of the working agent used. A reversible engine is one having an efficiency ratio of 100 per cent., and it has commonly been assumed that the theorem still held for actual heat engines, the efficiency ratio of which may be anything between say 50 per cent to 80 per cent.

In comparing the observed gains due to the use of superheat with those theoretically due, the theory adopted has been based on the assumption that the effective thermo-dynamic head was proportional to the adiabatic heat drop. This effective thermo-dynamic head is, however, equal to the adiabatic heat drop multiplied by a "reheat factor," due to the fact that all the energy expended by friction in the higher stages of the turbine is returned to the steam as heat, and this addition of heat increases the amount available for doing work in the later stages of the turbine. It is easy to show that this reheat factor‡ is not independent of the character of the working fluid. As indicating the practical importance of this fact consider the case of a turbine supplied with steam so highly heated that the superheat is not lost before discharge to the condenser takes place. Then if the ratio of the initial to the final pressures be 200 to 1, and the hydraulic efficiency of the turbine 70 per cent., the reheat factor will be 1.1643, or, in other words, the effective thermo-dynamic head will be about 16½ per cent. greater than the adiabatic heat drop. If, however, we take another turbine, supplied with saturated steam at 200 lb. absolute and exhausting at 1 lb. absolute, the reheat factor corresponding to the same hydraulic efficiency will be only 1.0559, or, say, but 5½ per cent. more than the adiabatic heat drop.

The physical explanation of the reheat factor

* Proceedings of the Royal Society, vol. xci, 1914.
† "Scientific Papers," vol. ii, page 237.
‡ For gases it is given by the relation

$$R = \frac{1}{\eta} \cdot \frac{1 - \left(\frac{p_2}{p_1}\right)^{\eta\left(1-\frac{1}{\gamma}\right)}}{1 - \left(\frac{p_2}{p_1}\right)^{1-\frac{1}{\gamma}}}$$

where p_1 and p_2 denote the initial and final pressures respectively, γ is the specific heat ratio, and η is the hydraulic efficiency of the turbine. This formula is not applicable to wet steam, but an exact method for use in this case was described in ENGINEERING, vol. 79, page 38.

being higher with certain gases than with others may be of interest. The energy lost in friction in the higher stages of a turbine is returned to the working fluid as heat and causes the pressure of the fluid to be higher at the later stages than it would be at the same specific volume if there were no frictional losses. When heat is added to gas at constant volume, the corresponding energy goes in part in increasing the average velocity with which the molecules move, and in part to increasing the rate at which these molecules spin, and it may be also in part to intensifying intra-molecular vibrations. The pressure developed by a gas depends solely on the velocity with which the molecules move, and not at all on the rate at which they spin or at which their component parts vibrate. Hence only that fraction of the heat energy supplied which goes to increase the velocity of the molecules is recorded as pressure, and the greater the number of modes in which this supply of energy is divided up, the less the pressure developed for a given addition of heat. In the case of the monatomic gases, such as argon, helium and the like, the molecules are spheres, which acquire no spin under their mutual collisions. The whole of any heat added to such a gas (at constant volume) is, therefore, effective in raising the pressure, and were a turbine operated with such a gas the reheat factor would have its maximum value, being 1.256 when the pressure ratio is 200 to 1 and the hydraulic efficiency 0.7. In this connection it may be noted that mercury vapour has also spherical monatomic molecules, and Mr. W. L. R. Emmet, of the General Electric Company, described a mercury vapour turbine in a paper read before the American Institution of Electrical Engineers in 1914. If this vapour were superheated the turbine would benefit by an abnormally high reheat factor.

In the case of diatomic gases only three-fifths of any heat energy supplied at constant volume goes in developing pressure, the remainder merely increases the rate at which the molecules spin; whilst with still more complicated molecules still less of any heat energy supplied is effective in generating pressure. In case of water vapour a certain proportion of double molecules are always present, otherwise the reheat factor would be the same as for diatomic gases. These double molecules are not only capable of spinning about three coordinate axes instead of two, but the bond between the components is far from rigid, and hence these double molecules have a low reheat factor. Further, as the temperature rises the number of these double molecules present diminishes, so that some of the heat energy supplied goes in breaking the bonds between the two components. This still further reduces the heat available for increasing pressure, and the result is that the value of γ for superheated steam is 1.3 instead of 1.4, which would be expected were no double molecules present. With wet steam matters are still worse, since much of the heat added goes in evaporating the particles of suspended moisture, a fact which sufficiently accounts for the low reheat factor characteristic of such steam.

Although a considerable proportion of the anomaly in superheat correction is accounted for when the difference in the reheat factors of wet and superheated steam is taken into consideration calculation shows still outstanding discrepancies.

These appear mainly attributable to the fact that the steam passing through a turbine is under-cooled or super-saturated during a substantial proportion of its total range of expansion. Indeed, Professor H. L. Callendar, in a paper contributed to the Institution of Civil Engineers in 1898, gave reason for believing that this condition of affairs also obtained in the cylinders of ordinary reciprocating engines. If this be true, and for our own part we do not question it, the determination of the "missing quantity" at different parts of the stroke of such engines by a study of the indicator diagram is grievously complicated, to say the least, since all methods so far proposed for this determination assume that the steam is in thermal equilibrium throughout the whole of its expansion.

In a turbine the conditions are much more favourable to the phenomenon of under-cooling, and there are strong theoretical grounds for believing that it actually occurs to a very high degree. Direct experimental evidence of the fact is, however, very difficult to secure. This was pointed out by Callendar in the paper already cited. Any thermometer placed in superheated steam indicates, not the temperature of this steam, but that of the film of water which is immediately deposited on the bulb. The temperature of this film tends to be in equilibrium rather with the pressure than with the temperature of the surrounding steam. Hence a very high degree of under-cooling may be represented by a defect in the thermometer reading of but a few degrees. Theory indicates that a high degree of under-cooling does not persist throughout the whole range of expansion, and in ordinary turbine practice the maximum to be expected in the exhaust steam is not more than some ¼ deg. C., although at some previous stage the steam may have been undercooled some tens of degrees. The higher the initial superheat of the steam the longer is condensation delayed, and with very high superheats, therefore, the steam may be exhausted in a greatly undercooled condition.

We are indebted to Mr. W. Chilton, of the Brush Electrical Engineering Company, Limited, Loughborough, for the results of some very careful observations made in these conditions. These are reproduced below:—

	¼-load.	½-load.	¾-load.
Exhaust pressure, inches of Hg...	0.671	0.554	0.569
Corresponding temperature, F.	deg. 67.2	deg. 61.6	deg. 62.3
Observed temperature, F.	61.0	57.2	60.3

The readings were taken at the turbine exhaust branch, and the conditions precluded the possibility of the low readings being due to conduction losses. For reasons already given the defect of 6 deg. in the trial at half-load probably corresponds to an undercooling of the exhaust steam by perhaps-some 40 deg. or 50 deg. F.

Theory indicates that the loss due to undercooling is less the longer the phenomenon is delayed. As it can only occur within the saturation field, the effect of superheat is to postpone the production of the super-cooled condition to the later stages of the turbine, with a consequent reduction in the under-cooling losses. We hope in a future issue of ENGINEERING to set forth in detail the theory, of which the conclusions have been summarised above.

RATES AND WAGES ON THE FRENCH RAILWAYS.

As we have pointed out in former articles, there is a dearth of rolling-stock on the French railways, and a very large proportion of the existing railway material is being utilised for meeting the needs of the army. Moreover, the working of the railways, instead of being in the hands of civilian experts, is entrusted to the military, and the latter either lack initiative or are unable to exercise the initiative they have. As a consequence, the transport and delivery of commercial goods is considerably delayed, the delay corresponding in itself to an increase in the cost of carriage, and for these reasons the proposed increase in the tariffs on the French railways, an increase which has been contemplated for some time past, is viewed with grave concern throughout France. The railway tariffs which now obtain in France are not high compared with those which rule in other countries, as far as a comparison can be instituted in this respect. We may here state that in 1892 M. Yves Guyot, at that time Minister of Public Works, obtained from the railway companies a reduction in the railway rates as laid down in the specifications annexed to their concession contracts, and the reduction was granted by them in exchange for the removal of a tax which was formerly collected by the State on all railway transports, a tax which formed a heavy burden upon the companies and acted as a deterrent to any possible development of the railway traffic. But even before this took place the railway companies had, at various periods, allowed reductions in their general rates and had granted concessions in the form of special rates for certain classes of goods. In this connection we may remark that, as a general rule, before any such facilities by the railway companies are applicable, they have to be approved by the State; a rate thus approved by the State, however low it may be, cannot later be raised by the companies without an authorisation from Government.

The basis of the reform made in the French railway tariffs in 1892 was the abolition of a 10 per cent. surcharge which had been added in 1871 to increase the Treasury receipts, after the Franco-German war. The French railway companies had undertaken as early as 1883, when new lines had been conceded to them and when they had actively worked for the increase in the railway system throughout the country, to reduce the price for single passenger tickets calculated on the maximum rate on the day the State would cancel the said surcharge. The railway companies granted in reality much larger reductions than those they promised, bearing notably on return tickets, reductions which amounted to about 4 per cent. for second-class and 15 per cent. for third-class tickets. This corresponded to a sacrifice on the part of the companies of 38,000,000 francs (1,520,000*l.*) annually, the yield of the tax to the State, the tax which was done away with in 1892, having been 39,000,000 francs (1,560,000*l.*).

The passenger rates hitherto charged on the French railways appeared to be notably below those charged in Great Britain, slightly higher than the Belgian rates, and approximately equal to the German rates if the three German classes alone be considered, the fourth German class having for effect a reduction in the German average. When dealing with the situation of the French railway passenger, the fact should not be lost sight of that he can carry free 30 kg. (66 lb.) of luggage, and that numerous combinations, such as workmen's trains, special return tickets, sea coast, family and other special tickets, reduce the cost of ordinary tickets, a cost which in itself is already below the maximum rate provided for. This maximum rate is 11.20 centimes per kilometre (1.8*d.* per mile) first-class, 7.56 centimes (1.2*d.* per mile) second-class, and 4.928 centimes (0.7*d.* per mile) third-class, except on the State railway system, on which "generosities" are readily granted to get the public to approve of State ownership. On the State system the rate for first-class is at the present time 10.192 centimes per kilometre (1.6*d.* per mile). As against the above maximum rates, the rates actually charged were about 5 centimes per kilometre (0.8*d.* per mile) first-class and 3 centimes (0.48*d.* per mile) second-class. For workmen's tickets, on special runs, the rates have frequently been on the basis of 1 centime and even ½ centime per kilometre (0.16*d.* and 0.08*d.* per mile). The mean rate per passenger carried has seldom ever risen above 4.20 centimes per kilometre (0.67*d.* per mile) and has frequently been as low as 3.20 centimes (0.5*d.* per mile). Mr. Hason Thompson, of the Chicago Railway News Bureau, has calculated the average receipts per passenger and per mile on the whole of the French railway system at 1.08 cents. For the German railway system he found 0.91 cents, but in this latter connection the existence of a fourth class in Germany has to be reckoned with. He found the average to be 1.51 cents for the railways of the United Kingdom, and 0.70 cents for those of Belgium.

In regard to goods rates, these hitherto were really low on the French railways. Wagons were always available for the transport of goods, and the railway companies have borne practically every responsibility for their safe delivery. Since the war broke out matters have, of course, altered in respect to commercial traffic. A short time previous to the outbreak of hostilities a large reduction had been granted in the rates for the carriage of corn, manure, coal, iron and steel and building material, and the mean rate per ton-kilometre was 4.47 centimes (0.71*d.* per ton-mile), the German mean rate being 4.55 centimes (0.73*d.* per ton-mile); the German railways, moreover, undertake practically no responsibility for damage and delay.

The special tax on express-speed deliveries on the French railways was done away with in 1912, which improved matters considerably for a large variety of goods. In regard to the transport of goods, Mr. Hason Thompson finds the medium receipts per ton-mile to be 1.30 cents for France, 1.37 cents for

Germany, 2.33 cents for the United Kingdom—where, it is true, cartage intervenes to increase the figure—and 1.13 cents for Belgium.

It is feared that the necessity in which France will be placed to increase both the passenger and goods rates will have a heavy reaction upon the economical life of the community. On the other hand, the increase in the tariffs will be comparable to a tax paid to the State by every member of the community. Moreover, a similar measure has been taken in most other countries.

The increase proposed in France is due to the increasing deficits in the railway balance sheets since the outbreak of hostilities, deficits which will be increased in the near future by the grants which Government intends to allow to the railway staffs and which will be payable even before the increases in the railway rates yields increased receipts to the railway companies. The deficits are traceable to the mobilisation of the railways for war purposes and to the increase in the price of all commodities, especially coal. We may here state, as an illustration, that in 1913 the total commercial receipts of the French railway companies and of the two State railway systems amounted to 2,007,000,000 francs (80,280,000*l.*); the total fell to 1,671,000,000 francs (66,840,000*l.*) in 1914, only five months of which were covered by the war. Of this latter total, 1,479,500,000 francs (59,220,000*l.*) represented commercial receipts, the balance being receipts for military transport. The total receipts for 1915 were 1,698,000,000 francs (67,920,000*l.*), in which the commercial receipts entered for 1,327,000,000 francs (53,080,000*l.*) and the military receipts for 371,000,000 francs (14,840,000*l.*). The working for 1916 is calculated to yield a total of 1,989,000,000 francs (79,560,000*l.*), in which the commercial receipts will enter for 1,464,000,000 francs (58,560,000*l.*); the military receipts will form a total of 525,000,000 francs (21,000,000*l.*). This latter figure appears high at first glance, but it really corresponds to a loss, and the loss is the greater the larger the sum paid by the State for the military use of the lines. The above figures show a rise in the commercial receipts, this affording a proof that the community is gradually adapting itself to war conditions and that business is on the increase. But, unfortunately, the total expenditure is gradually rising also. There was, in 1914, a decrease in expenditure, compared with 1913, because for a time there were no outlays whatever. But in 1915 the total expenditure was 2.70 per cent. above the figure for 1914, the total for 1915 being 2,069,000,000 francs (82,760,000*l.*). It is calculated that the total expenditure for 1916 will reach 2,443,000,000 francs (97,720,000*l.*), or an increase of over 18 per cent. on the figure for 1915 and of about 19 per cent. on that for 1913.

If we take the figures as a whole we find for 1913 an insufficiency in receipts of 42,000,000 francs (1,680,000*l.*), which proceeds mostly from the State railway systems; for 1914 the total deficit was 343,000,000 francs (13,720,000*l.*); the figure for 1915 was 371,000,000 francs (14,840,000*l.*); whilst for 1916 a deficit of over 450,000,000 francs (18,000,000*l.*) is anticipated.

The cost of coal weighs exceedingly heavily upon the budget of the French railways. In 1913 the Paris–Lyons–Mediterranean Railway Company spent 56,000,000 francs (2,240,000*l.*) on coal; it spent over 85,000,000 francs (3,400,000*l.*) in 1915, and in 1916 its coal bill will, according to every probability, exceed 170,000,000 francs (6,800,000*l.*). The other railway systems can also show a greatly enhanced coal bill. Rails which cost 180 francs (7*l.* 4*s.*) per ton before the war now cost over 550 francs (22*l.*) per ton. The price of sleepers has risen from 5 francs (4*s.*) to about 11 francs (8*s.* 10*d.*) each. The cost of rolling-stock is also exceedingly high at the present time. In fact, many requisite articles are now quoted at prices 200 per cent. higher than pre-war prices.

In the case of the railway companies which still come under the State guarantee of interest clause, and in that of the State systems, the deficits are liable to be made good by the budget of the nation, but this latter budget is overcharged as it is. The remedy must consist in calling upon every class to share in making up the balance, and this seems the most logical way out of the difficulty. In the case of the Northern of France Railway Company and of the Paris–Lyons–Mediterranean Railway Company, which no longer have the benefit of the State guarantee of interest, the deficits have been counteracted by bond issues and by reduction of dividends; but in the instance of these two companies also an increase in rates seems a logical way of solving the problem.

It is not expected that the increase in the railway rates can be effected with any degree of rapidity; the operation is an extensive one, difficult to carry out satisfactorily, one which will require full consideration on the part of the various railway boards and approval on the part of the Ministry of Public Works. In the meantime, it is said that the State is to advance to the companies the sums these latter will require until they are able to collect the increased rates. According to a preliminary convention on the subject recently arrived at between the State and the railway companies, these latter, immediately upon the final approval of the increases in the tariffs, will be compelled to pay into the Treasury the advance funds they have received provisionally. The advance funds are to be paid back to the Treasury without interest.

For many years past the State itself was constantly urging the railway companies to reduce their rates with a view to meeting repeated demands on the part of the public. Notwithstanding this, says our Paris correspondent who sends us the above information, no surprise need be felt at the alacrity with which the State now proposes to advance funds to the railway companies for the purpose in view, *i.e.*, an increase in railway rates, at a time when the budget is already overburdened, and to allow increases to be made in the railway rates. The intention of the State, it is said, is to increase from a purely democratic, or even demagogic point of view, the wages of the railway staffs, numbering some 350,000 men who have votes. It is true that these men suffer from the increase in the cost of living, but in this respect they are no worse off than the remainder of the population. Moreover, their work is secure, they are paid regularly, and have the advantage of the stores instituted by the railway companies, which supply provisions at cost price. Apart from that, the men's wages are not at all low.

A stoker on the State railway system commences with a minimum wage of 1,920 francs (76*l.* 16*s.*) for 313 days' work at most, and he is practically sure to reach a total wage of over 4,000 francs (160*l.*), whilst a driver can easily reach a total wage of 6,000 francs (240*l.*) and over. On the Northern Railway system every man whose technical capacities have been found satisfactory after a preliminary trial has a wage of 1,800 francs (72*l.*) if stationed in Paris. As a contrast, we may state that the men employed as carriers at the Paris Central Market earn less than 6 francs (4*s.* 10*d.*) per day, the salary of the custom-house officer is only 1,000 to 1,150 francs (40*l.* to 46*l.*), and that the average wage of a workman in France is about 25 francs (1*l.*) per week, unless he have a specialty, when he can earn 35 francs (1*l.* 8*s.*) per week. The man who enters the service of the State railways as a track layer, where no professional knowledge is required, commences with a wage of 1,500 francs (60*l.*), his wage is raised periodically, and reaches easily 2,150 francs (86*l.*), the man continuing at the same unskilled work. A railway porter in a Paris terminus had a fixed wage of 700 francs (28*l.*) only, but he receives on an average 10 francs (8*s.*) per day in tips; the tips amount frequently to 40 francs (32*s.*) per day in the summer months. The guards' wages amount to 2,200 francs (88*l.*) on the State Railway system and to 2,350 francs (94*l.*) on the Northern Railway Company's system.

Apart from their wages, the men have all sorts of advantages in the form of pensions, medical aid, holidays with full pay or half-pay, free travelling passes, indemnities for large families, and indemnities when stationed in towns where living is expensive. These items of expenditure are styled "paternal outlays," and these amounted to over 25,000,000 francs (1,000,000*l.*) in the last balance sheet (for 1915) issued by the Eastern of France Railway Company, corresponding to an increase of 30 per cent. on the fixed salaries and wages. The corresponding figure for the Paris–Lyons–Mediterranean Railway Company was 33,000,000 francs (1,320,000*l.*); it was 31,500,000 francs (1,260,000*l.*) in the case of the Paris–Orleans Railway Company.

The increase which it is intended to grant in the salaries and wages of the French railways' staff is calculated to reach an annual total of 80,000,000 francs (3,200,000*l.*). It is proposed that the increase shall start as from November 1, 1916, and remain in force for one year after the cessation of hostilities. The increase is to be based on the wage, or on the number of children below 16 years of age.

In regard to the increase in the railway rates, an advance of 15 per cent. is mentioned; this would not markedly increase the price of the goods carried. The average yield of a ton of goods on the French Railways is 5.40 francs (4*s.* 4*d.*) for an average run of 129 km. (80 miles). An increase of 15 per cent. would mean a surcharge of 80 centimes per ton (about 8*d.*). For household coal, this would correspond to 10 centimes per 100 kg. (about 10*d.* per ton) carried a distance of 300 km. (186 miles), the value of the 100 kg. of coal being now about 17 francs (6*l.* 16*s.* per ton), or 11 francs (4*l.* 8*s.* per ton) higher than the pre-war quotation. For bar-iron, the advance would work out at 18 centimes per 100 kg. (about 1*s.* 6*d.* per ton) over 300 km., the value of the bars being 22.50 francs per 100 kg. (9*l.* per ton). For steel rails it would also work out at 18 centimes per 100 kg. over 300 km.; for cotton the increase would mean 42 centimes per 100 kg. (3*s.* 5*d.* per ton) over 300 km. But since the increase in the railway rates is primarily to compensate for the increase in the railwaymen's wages, it will be necessary to make still further increases in the rates in order also to meet the increased cost in every commodity, particularly coal, and the direct result will be high cost of railway transport throughout the French railway systems.

THE GERMAN TEXTILE MACHINERY INDUSTRY.

THERE is a very large textile industry in Germany, much of it being carried on by British machinery. The German machine manufacturers have, however, applied themselves with great ability and perseverance to capture this trade, and they have been largely successful. Not only have they succeeded in their own market, but they have also built up an export trade of considerable dimensions which meets us in the neutral markets of the world. For some years prior to the war the export trade had been increasing, and its volume, together with that of the home market, has given employment to a great number of machine works. The importance of these will be understood from the following statistics, which we take from a recently issued report. After the war there will be a fierce struggle to maintain the position, which has been gained by great exertion and expense.

There are at present 223 factories in Germany which manufacture machines for the textile industry. Of this total 30 factories have made machinery for spinning, &c., their speciality, 106 factories construct machinery for weaving, knitting, &c.; 109 manufacture plant for dyeing, bleaching, &c. This latter section comprises laundry machinery. Of the larger factories 12, in addition to textile machines, manufacture machine tools, refrigerators, &c., but only their manufacture of textile machinery is dealt with in this report. Twenty of the factories manufacturing textile machines are limited companies; these are the largest concerns and employ 40 per cent. of the total number of hands employed in the manufacture of textile machinery.

In the year 1913 there were about 28,000 hands employed in the manufacture of textile machinery in Germany, and of these 5,800 were engaged upon machinery for spinning, &c.; 14,200 upon machinery for weaving, knitting, &c.; and 8,000 on the last of the three above-mentioned sections. In the second group about 4,800 hands were engaged in the manufacture of looms and a similar number in the making of knitting machinery, &c.

The textile machinery industry is principally confined to the Kingdom of Saxony and the Rhineland-Westphalia district, that is, the parts of

Germany, where the textile industry particularly flourishes. In the 25 Chemnitz factories for textile machinery 12,000 hands are employed, and in the whole of Saxony about 16,000. The manufacture of textile machines is also to the front in Alsace, where about 5,000 hands are employed. There are also factories in Würtemberg, Thuringia, Pfalz, Brandenburg and Silesia.

There is no comprehensive official record of the value of the production of the German textile machinery industry. In order to arrive at a result, various estimates have been formed which make the aggregate value of this manufacture some 100,000,000 to 120,000,000 marks per annum. This means about one-twentieth of the total value of Germany's manufacture of machinery, which has been put at 2,500,000,000 marks, the work of 543,000 hands.

The average value of the exports of textile machinery for the years 1910-13 and the first half of 1914 amounts to 44,600,000 marks, against corresponding imports of 15,400,000 marks; that is, about 40 per cent. of the production was exported, whilst the imports amounted to about 13.5 per cent. of the manufacture. Imports of the value of 8,250,000 marks were spinning machinery, &c., and of this, again, 80 per cent. were cotton-spinning machines, of which more than four-fifths came from England and the balance from Switzerland. Against this latter import stand exports of a value of 2,000,000 marks, principally from Alsace to France and some to Russia. More important is the export of "Streichyarnspinnereimaschinen" (carded yarn spinning machines), which amounts to 35 per cent. of the total export under the first section. Against this stands an import of only 90,000 marks value. The decided superiority of this speciality of German manufacture has won for itself a valuable position on the international market, and the German exports exceed half the production.

It is also worth noticing that the export surplus of the "Bastfaser" (hemp yarn) spinning machines amounts to some 1,500,000 marks, this proving the development of this comparatively new branch in the German textile machinery industry, which was formerly entirely British.

In the second section of textile machines the average annual exports from Germany amount to a value of 24,250,000 marks, against imports amounting to 4,750,000 marks. Of the latter, 2,750,000 marks represent weaving machines, 1,000,000 marks looms for window curtains and tulle, and 750,000 marks machines for twisting and jack frames. The corresponding figures for the export are respectively 9,000,000 marks, 1,500,000 marks and 2,000,000 marks, besides 5,250,000 marks for "Wirk" and "Strick" machines and 6,500,000 marks for "Breitstick" machines. The German manufacturers have found it impossible to compete against the light, simple and cheap English looms, although they have been very successful in regard to curtain and tulle frames, the greater part of which have been exported to the United States.

In machines for washing, finishing, &c., there is a substantial export surplus. The export of "Ausrüstung" (auxiliary) machines amounts in value to 9,000,000 marks, against imports of only 750,000 marks. Of washing machines the exports represent a value of fully 2,750,000 marks, against imports of barely 1,750,000 marks, which arises from the German preference for extremely expensive American machines, large and small.

Almost all machines wanted in the complicated textile industry are manufactured in Germany. This industry asserts that it does not receive any effective protective tariff. The German duty is generally 4 to 6 marks per 100 kg. (40*s.* to 60*s.* per ton), according to the weight of the different machines, the 4-mark duty applying to most. On most looms, reckoning them at an average value of 60 marks per 100 kg., this only comes out at 6⅔ per cent. on the selling price. In the matter of machines which have an established reputation, this is really of no importance. In addition, the home railway freight often neutralises this difference. Thus the freight from Chemnitz to Aachen, on textile machines used there, almost amounts to as much as the import duty from Belgium. In the same way the freight from Chemnitz to the North Sea ports and Rhineland-Westphalia exceeds the freight from England several times. Such differences in freight also play a part in the export of German textile machines to Belgium, Holland, France, Italy, Spain, &c.

In machines for cotton spinning and weaving Germany's exports are insignificant, amounting in value only to 1,000,000 marks annually, principally from Alsace to France, and a portion to Russia. To the latter country Germany supplies all kinds of textile machines, about one-fifth of the entire German export of textile machines going to Russia and about the same quantity to Austria-Hungary. Of other European countries Scandinavia, France and Italy receive about equal amounts. England takes some cotton, coarse, and "Streichyarn" spinning machines, as well as some "Ausrüstungs" machines, specialities in which the English makers have been almost completely forced out of the market. To North America Germany principally exports weaving looms and embroidering machines.

On the world market the German textile machine industry principally has to face English competition. In Europe, textile machines are manufactured in Switzerland, from whence cotton-spinning machines and looms are imported into Germany; in Austria, which, however, is able to cover only a part of her own requirements, although also exporting to the Balkans and Russia; in Belgium, where in Verviers all machines for "Streichyarn" woollen yarns are manufactured, and from whence the exports amount to the value of some 3,000,000 marks per annum, principally to France, Italy, Spain and Portugal; and in France, especially for silk handling and auxiliaries, in which also an export to Germany takes place. In Russia there were factories for textile machines in Lodz, Zgierz and Bialystock, especially for "Streichyarn" coarse cotton-spinning and simple looms; in Sweden and in Spain a textile machine industry is beginning, and in the United States there exists a developed textile machine industry, which tries to satisfy the home requirements as regards fine cotton spinning and "Streichyarn" spinning, looms and "Ausrüstung." The inventive gifts of the Americans have also been brought to bear upon the development of textile machines. In this connection may be mentioned the broadcloth loom, the self-shuttling loom, the ring frame, the "Wagenspliser," and the round knitting machine.

The export from Germany of textile machinery parts is also of some amount, in value about 5,000,000 marks in the year, or more than 10 per cent. of the aggregate export of textile machines.

It is peculiar to the textile machine industry that many parts are made at works which turn out only one article. In Germany there are some 120 factories which produce such textile parts, with an annual average export worth 15,660,000 marks, against which come imports of 5,000,000 marks. In this branch several thousand hands are employed, and the import is principally confined to shuttles, spindles, carding machine parts covered with cards, and weaving protection and picker protection. Of importance is the export of "Kratzen" fittings, needles and wire parts and the engraved copper printing rollers. Of the 120 factories which manufacture auxiliary parts and fittings for textile machines, 14 make shuttles of wood, paper and plate; 24 make spindles and other spinning-machine parts; 10 make "Kratzen"; 5 leather goods for the spinning industry; 31 make loom fittings; 9 make needles; 7 make other parts; 13 make fittings for "Ausrüstung," including printing cloths, roller fittings, &c.; 4 make testing appliances; and 5 pattern-cutting machines.

The war has injured the German textile machine industry, but an export has been kept up to Austria, Scandinavia, Switzerland, Holland and, until the declaration of war, to Italy.

NOTES.

Future Prospects of Light Production and Magnesium.

Though known chiefly as a distinguished electrical engineer, Dr. Charles P. Steinmetz, when addressing the American Illuminating Engineering Society last autumn, did not hesitate to characterise the Welsbach lamp as representing most probably the most radical advance that had been made through all ages in illuminating engineering. For the first time, he thought, energy had in that case been converted into radiation outside of the temperature law. There were methods of light production in use which were not based directly on heat as an intermediate form. Yet modern lighting, and electric lighting in particular, was based on temperature radiation, and in the field of temperature radiation and filament lighting the acetylene lamp and the gas-filled Mazda lamp might be credited with the highest efficiency. In increasing that efficiency enormous progress had been made in the last fifteen years, during which the efficiency of the glow lamp had been raised from 4 watts per candle to ½ watt per candle. The advance could not progress at anything like a similar rate, since applied science was approaching the limits of efficiency attainable under the temperature radiation law. In lamps burning hydrocarbons as gas or vapour the source of chemical energy was limited by the dissociation temperatures of the oxides of carbon and of hydrogen. That limit had nearly been reached; but the use of radiators which had higher dissociation temperatures offered some promise. Magnesium oxide was such a material. If the price of magnesium could be lowered, as the price of aluminium had been lowered, this metal might become a commercial competitor of the hydrocarbon flame. Now the manufacture of metallic magnesium had been much developed during the present war, and it was quite likely that magnesium would be obtainable at reasonable prices after the war. We recently drew attention to the various ways of isolating magnesium which are now under trial, and magnesium salts are, of course, abundant and, so far, little utilised. Chemical luminescence, Dr. Steinmetz concluded, was, after all, not merely temperature radiation. Heated electrically, or protected from the flame gas of the burner, the Welsbach mantle did not give the spectrum which it gave when used in the lamp. The mantle luminescence had the characterisation of a fluorescence, *i.e.*, the radiation of one material excited by the radiation of another material present in small quantities. Selective emission might be a more general feature than was generally assumed. From a paper communicated by Mr. W. M. Grosvenor to the American Electro-Chemical Society we learn that, in 1913, the United States imported 38,000 lb. of metallic magnesium, chiefly from Germany; the price was then about 1.45 dols. per lb. The price subsequently rose to 10 dols., but was, in 1916, down to 5 dols. again because France and England had successfully started magnesium works, and the two American magnesium works could alone cover the general demand of the country; a third American firm makes magnesium only for munitions.

Copper Statistics.

Going back twenty years, we find that the world's production of copper steadily increased up to 1912, when the total production reached its maximum of 1,024,100 tons. The term production is to cover the copper obtained or obtainable from the ores mined. That the year 1913 showed a drop in the total production, to 1,002,300 tons, was mainly due to the internal troubles in Mexico, which had become second in the order of the copper-producing or mining countries; Mexico produced in 1912 and 1913 respectively 73,700 and 52,800 tons. The United States have always headed the list with up to 58 per cent. of the total copper production, and the statistics of the *Engineering and Mining Journal* and of the Metallgesellschaft of Frankfort (which we take from the *Schweizerische Bauzeitung* of December 23, 1916) credit the United States, in 1913, with a production of 557,400 tons of copper, against 224,000 in 1897. Japan, which had only mined 13,500 tons of copper in 1897, came up to the second place in 1913 with 73,200 tons. Then followed Spain and Portugal, with a production of 54,700 tons, a figure which has fluctuated little in the last twenty years; Australia, with 47,300 tons (17,300 in 1897); and Chili, with 40,000 tons (22,300 tons). Chili is now said to mine 10,000 tons of ore daily at Chuquicamata, at present the largest copper mines (still being enlarged) in the world, which are situated 10,000 ft. above sea-level and receive electric power

at 110,000 volts. The countries next in order were, in 1913: Canada, 34,900 tons; Russia, 33,900; Peru, 25,700; Germany, 25,300 tons; Serbia, 6,400 tons, and Katanga (Belgian Congo), 6,900 tons, had only in recent years joined the list of copper-producing countries. With the war, the copper production decreased in most States, to rise again in 1915. The figures for 1914 and 1915 are: United States, 525,500 and 646,200 tons; Mexico, 36,300 and 31,000; Japan, 72,800 and 75,000; Spain and Portugal, 37,100 and 35,000; Australia, 37,600 and 32,500; Chili, 40,900 and 47,400; Canada, 34,000 and 47,200; Russia, 31,900 and 26,000; Peru, 23,600 and 32,400. Germany is the only country (next to Chili) which has steadily gone on increasing its copper production, the figures for 1913, 1914 and 1915 being 25,300, 30,500, 35,000 tons; the increase is all the more remarkable, since the copper ores of the Lower Harz Mountains and the Mansfeld district are by no means rich. The world's totals for 1914 and 1915 were 927,200 and 1,061,600 tons. We should mention that the various statistics are not always quite in accord; not all the figures are reliable, and it is not clear in how far stores from the preceding year may have been carried over. This applies particularly to the estimates of output of mines, A, copper production in metallurgical works, B, and copper consumption in the country, C, to which we now turn; all these figures concern the year 1913. The figures for the United States were: A 557,400, B 589,100, C 348,100 tons. The other parts of America, although important as regards A and B, were only assigned a consumption of 3,000 tons. In Europe, Germany headed the list with reference to C, the figures being, A 25,500, B 41,100, C 259,300 tons; the United Kingdom, coming next, is credited with, A 300, B 52,100, C 140,300 tons; France, A 0, B 11,900, C 103,600 tons; Russia (including Russia in Asia), A 33,900, B 34,300 C 40,200 tons; Austria-Hungary, A 4,100, B 2,300, C 39,200 tons; Italy, A 1,600, B 2,300, C 31,200 tons; Belgium, C 15,000 tons; Europe, totals: A 139,600, B 186,400, C 643,100 tons. These figures, whether quite reliable or not, certainly show that the United States, Germany, England and France together consume more than 80 per cent. of the world's production of crude copper. It is further estimated that, deducting exports of manufactured copper articles, Germany actually consumed 198,300 tons, the United Kingdom 140,300 tons, France 95,900 tons, Russia 39,100 tons, and Austria-Hungary 36,600 tons of copper, each country for its own use.

LARGE POWER CHAIN-DRIVE.—According to *The Canadian Engineer*, a chain-drive of 5,000 h.p., said to be the most powerful chain-drive in the world, is in operation in a hydro-electric plant on the Snake River, in Oregon. Two water-wheel shafts, which run at 149 r.p.m., are connected by four driving chains with a generator shaft which is driven at 225 r.p.m. Each of the former shafts carries a 71-tooth sprocket wheel, 45½ in. in diameter, and the generator shaft has two 47-tooth sprockets, a little over 30 in. in diameter. The water-wheels drive sets of four chains, each of which is over 31 ft. long, 21 in. wide, and weighs 2,800 lb. The chains have been tested to a stress of 40,000 lb. per sq. inch. A chain-drive was not contemplated for the plant originally, but in the midst of its construction, and after part of the machinery had been delivered, financial difficulties interrupted the work. After some time experts recommended the chain-drive as the most economical means of utilising the available equipment.

THE STUDY OF CHINESE AND THE CHINA MARKETS.—The American Consul-General at Hankow, says the *London and China Telegraph*, remarks that for a long time business men have considered it important, when exploiting a market, to have some knowledge of the language of the country, but this has not held good in regard to China. The Chinese language has been considered unnecessary for merchants, and too difficult for the average Occidental to acquire. Of late, however, this impression has been somewhat shaken, and many persons most capable of deciding have concluded that some knowledge of the Chinese language was very desirable. Such a conclusion would have long since been accepted as fact in any other part of the world except China. After noting the formation of classes for the study of Chinese at Shanghai and Hankow, the Consul-General observes that these efforts provide evidence of the opinion that such a training is a necessity. While all students pay their own tuition, it is said some of the firms have offered inducements for joining, by promising bonuses sufficient to cover the outlays as each year's study is satisfactorily completed.

ELECTRON, QUANTA AND RELATIVITY THEORIES.

TO THE EDITOR OF ENGINEERING.

SIR,—Like a great magician who knows what the Dalai Lama of Thibet will have for dinner, but not what we had for breakfast, Mr. Edwards gives us a column and a half of unverifiable assertions—while still evading the very simple question asked by me in regard to a statement of his which ought to be withdrawn, as it is not true that energy or momentum can *enter* anywhere.

In the first paragraph of his letter on page 18 of your current issue, Mr. Edwards twice mentions "matter *and* motion," which is sheer nonsense to anyone who realises the meaning of matter *in* motion; and I could not wish for a better example of the careless use of words and of the want of clear thinking than this further slip on the part of your learned correspondent.

London, January 6, 1917. SESAMY.

TO THE EDITOR OF ENGINEERING.

SIR,—As bearing on the "Theories of Relativity and Quantum," I beg to call attention to the following cuttings from technical journals of recent date:—

"It is rather difficult to grasp the fact that the same laws of Nature may hold when some bizarre system of co-ordinates is chosen. Suppose an observer A uses rectangular co-ordinates, and B, through some kink in his mind, uses polar co-ordinates without realising that he is doing anything unusual. For A a ray of light can travel along the straight line x = constant; but evidently it cannot travel along the circle r = constant, which is B's idea of a straight line. The answer is that B through his peculiar system of measurement will suppose that he is in an intense gravitational field; he will calculate the curvature in the ray of light produced by this field; and, making allowance for it, he will find that the light actually travels along its theoretical curve (*i.e.*, curve for B, but straight line for A). Thus the same general laws of Nature are satisfied for B as well as for A; and it might be difficult to decide which of them had got hold of the absolute rectangular co-ordinates."—*Nature.*

"The problem of the transference of energy by ether-waves has accordingly led us to the conception of a 'quantum' of radiant energy travelling undissipated through space. The reconciliation of Planck's well-known idea with the older and well-founded conception of spreading waves remains. The experimental evidence seems to indicate that both theories are true simultaneously; that radiant energy is both concentrated and indivisible, and at the same time spreads and is divisible. We are left to hope for a compromise between the old and the new mechanics which will not involve concessions fatal to either."—*Electrician.*

Given the "will to believe," it is possible to reconcile contradictions of every kind in the new systems of mechanics.

January 8, 1917. M.

THE POWER-FORGING OF CHAIN CABLES.

TO THE EDITOR OF ENGINEERING.

SIR,—With your kind permission I would like to make a few remarks on an article* published on page 351 of your issue of ENGINEERING, December 1, 1916. From this article it would appear that it is claimed that an entirely new process has been initiated in the Boston Navy Yard, U.S.A., but this is not quite the case. Since 1910 chain of the larger sizes has been manufactured under a similar process by Messrs. Brown, Lenox and Co., Limited, of Pontypridd. Now, as regards the claims made by the Boston Navy Yard. In 1912 the U.S.A. Naval Attaché in London asked to see the process of chainmaking at the works of Brown, Lenox and Co., Limited, and he was, as a matter of courtesy, shown this process at Pontypridd. About this time, the firm was completing a large contract for America, viz., the supply of chain cable and gear for the two Argentine battleships being built at the Fore River and New York Shipbuilding Yards, respectively, in America.

It may be interesting, by the way, to mention that at this visit it was pointed out to the attaché that some years previously the firm of Brown, Lenox and Co. had supplied the U.S.A. naval authorities with full drawings and particulars of dock-gate protection gear and guarding chains, a modification of which was used for the Panama Canal dock gates. It is noticed that the guarding chains for the Panama Canal dock gates are mentioned in the article in question, and it might also be mentioned that just before, and in the early part of the war, Brown, Lenox and Co. made a considerable quantity of these guard chains for the Panama Canal. This is by the way.

During the contract for the Argentine cables the firm brought out a catalogue, and one of the illustrations (enclosed) briefly described a new process (in 1911) of chainmaking. A copy of this catalogue was given to the attaché. A few months afterwards the then U.S.A. Naval Attaché in London wrote saying he had relieved the attaché first-mentioned, and he informed the firm of Brown, Lenox and Co. that their Boston Navy Yard were much interested in the new process of chainmaking, and asked for full description, with sketches, of the process. In an interview with the writer this further information was given, but as it was eventually lost, further copies, as reproduced below, were sent to the United States Naval Authorities.

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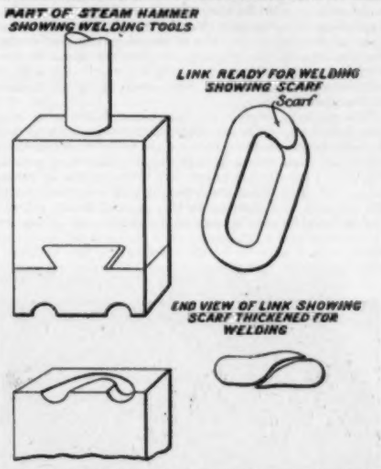
* "The Power-Forging of Chain Cables," being a paper read at the 24th general meeting of the Society of Naval Architects and Marine Engineers, held in New York, November 16 and 17, 1916.

Method of Manufacture of Chain-Cable Links when the Size of Iron exceeds 4½ in. Diameter (nominal size).

The links are properly scarfed, shaped and bent for welding, the thickened scarf being at the end, as shown on rough sketch on lithograph herewith.

They are then opened, threaded on to the next link in the chain, closed, and brought to a uniform welding heat in a furnace,


PART OF STEAM HAMMER SHOWING WELDING TOOLS
LINK READY FOR WELDING SHOWING SCARF
Scarf
END VIEW OF LINK SHOWING SCARF THICKENED FOR WELDING

which is constructed so that only the flame reaches the link, and there is no danger of scale or cinder getting between the scarf as in an open fire. The end of the link is then placed in a welding tool under the steam hammer and thoroughly welded by a few sharp blows from the hammer, the thickened end ensuring that the weld is a sound and clean one.

The article in question does not describe a new process, as it is essentially a description of the process which has been in existence since 1910, and the main features of this process were given as a matter of courtesy by Brown, Lenox and Co. to the United States Naval Attaché.

At this juncture it is not intended to go into the question of the merits of this new process, beyond pointing out that it is not a new process; we have found it useful, but have not considered it necessary to extend the process to all classes of chain. The writer, however, thinks it well that the article should be qualified by this explanation.

BROWN, LENOX AND CO., LIMITED
(Jas. B. Richardson, *Managing Director*)

ACCIDENTS AT AMERICAN METALLURGICAL PLANTS.—Fatal accidents reported at metallurgical works in the United States in 1915, says the *Iron Age*, were 68, of which 30 were at ore-dressing plants and 38 at smelting plants. In 1914 there were 23 and 33 respectively. These data are from the second report of the Bureau of Mines on accidents at metallurgical works, and cover returns from 110 smelting plants in 1915, as compared with 94 in 1914, and include copper, lead, zinc and quicksilver smelters as well as refineries, but do not include iron blast-furnaces. They represent also concentrating plants for copper, lead and zinc ores, stamp mills, cyanide plants and iron-ore washers. Non-fatal injuries at ore-dressing plants in 1915 were 2,095 and at smelting plants 5,718; they were 1,434 and 5,673 respectively in 1914. There were 63 permanent partial disabilities at ore-dressing plants and 87 at smelting plants. The total men employed were 49,891 in 1915 and 41,461 in 1914.

RENEWAL OF THE GERMAN STEEL UNION.—Of the three large combines within the German iron and coal industries, two have already brought about the requisite prolongation or renewal, viz., the Rhenish-Westphalian Coal Syndicate for a term of five years, and the German Pig-Iron Union to the end of the year 1920, but the German Steel Union still has this difficult task before it. According to the agreement concluded in the spring of 1912 the present Steel Union remains in force until June 30, 1917; if, however, no renewal or prolongation has been arrived at prior to March 31, 1917, the members of the Union are at liberty, from that date, to contract sales for delivery from the third quarter of 1917. The works in question have already held several conferences about the prolongation of the Steel Union, and the opinion seems to prevail that under the present circumstances it may be advisable to leave the conclusion of a new long-period agreement in abeyance, and instead adopt a provisional one extending over a comparatively short span of time. This arrangement has also found friends because the question of the A products is closely connected with that of the B products, which difficult problem can hardly be solved during the war. In the meantime, the Rombach Works, the German-Luxemburg Iron Works, the Peiner Rolling Mill and other works have withdrawn their notices concerning the much-vexed question of broad-flanged girders. This is looked upon as a good omen. The attempts to form Unions for the B products, or parts of them, by a renewal of the rolled wire Union, for instance, which was dissolved shortly after the commencement of the war, have in the meantime been abandoned, and the less stringent and comprehensive arrangements will have to do service for the time being.

CAST IRON: WITH SPECIAL REFERENCE TO ENGINE CYLINDERS.*

By J. EDGAR HURST, Manchester.

THE trend of advance in connection with modern prime movers, particularly internal combustion engines, would seem to be in the direction of the improvement of existing types rather than in the introduction of new types of engines. In this connection the materials of construction of the engines occupy no mean share of attention, and cast-iron, of which the vitals, the cylinders and pistons of engines are composed, is by no means of the least importance.

The subject, cast-iron, has been dealt with many times before, by this and other institutions, and no doubt its importance in this connection is fully realised.

It is an undoubted fact that grey cast-iron possesses unique and invaluable properties when in use as rubbing parts, and this being the case, one is surprised to find that much is still lacking in the way of actual scientific inquiry into the mechanism of the behaviour of cast-iron in this respect.

One or two aspects of the application of cast-iron to engine cylinder construction are of great importance both from a metallurgical and engineering standpoint, and the study of these has engaged the author's attention for some time past.

FIG. 1. SURFACE OF WORN LINER, SOMEWHAT REDUCED.

It must be borne in mind, however, that the subjects dealt with below are by no means fully exhausted, and an enormous amount of work still remains to be done before these points are thoroughly elucidated and entirely understood.

A brief synopsis of the paper is set out below, and it will be subsequently seen that the subjects are treated from an entirely metallurgical standpoint. This being the case, it is sincerely hoped that the matter contained in the following pages will prove of interest and value to engineers in assisting an understanding of these unique properties of cast-iron, and under such circumstances it is considered that no apology is necessary for bringing such a subject before this association.

SYNOPSIS.

Section I.

1. The Wearing of Cast-Iron.
2. Surface Flow Phenomena.
3. Anti-frictional Properties.
4. Micro-structure considerations.
5. Hardness and Wear.
6. Machining considerations.

Section II—on Growth.

1. General Considerations.
2. Heat Treatment of Grey Cast-Iron.
3. Effect of Heat Treatment on Engine Pistons.

Section III—on Chemical Constitution.

SECTION I.—THE WEARING OF CAST-IRON.

The wearing and anti-frictional properties of cast-iron are very intimately related and undoubtedly interdependent: but for the sake of clearness and simplicity it will be advisable to consider them under separate headings.

Wear for our purposes may be defined as the mutual loss in weight of two substances when rubbed together over a given period of time. Obviously when the number of substances with which and the number of modes in which cast-iron can be rubbed, and so bring about wear is considered, the subject becomes one of exceedingly wide dimensions. Therefore, for the purposes of this paper it is proposed to consider only the case of wear such as occurs in engine cylinders, that is, wear brought about by the mutual rubbing or abrasion of cast-iron by cast-iron.

The supreme difficulty experienced in all cases of wear is the lack of any satisfactory means of reducing industrial conditions to an experimental scale. And doubtless it is to this cause that research in this direction has been so long delayed. (It is interesting to note that wear experienced by road surfaces under conditions allied to those of actual practice is being investigated on a specially designed machine at the National Physical Laboratory for the Roads Board.) Of necessity, therefore, we have to rely for our knowledge of the subject on that chiefly derived from investigations of actual industrial cases—a very slow and prolonged method.

The characteristic feature observed on the usual examination of worn gas-engine liner surfaces, is that the whole of the worn surface is covered to a more or less extent with small pits or holes.

A typical example of such a surface showing this feature to a marked degree is illustrated in the photograph, Fig. 1. These holes or pits are commonly put down by many engineers to the coarseness of the grain of the cast-iron, and are often considered to be the holes from which the coarse plates of free graphite existing in the original iron have been detached. This is not strictly correct, for as a matter of fact on microscopical examination of etched specimens these holes prove to be the result of the detachment of whole grains of any constituent from that particular portion of the surface of the liner.

On subjecting worn liner surfaces to a microscopic examination one invariably finds the harder constituents standing in relief exactly as though the liner had been subjected to relief polishing. The examination of the photograph of Fig. 1 under an ordinary hand lens shows this, and the hard phosphide eutectic is to be seen distinctly outlined in relief in the micro-photograph, Fig. 2, taken from a section of Fig. 1. Further typical examples of the microscopic appearance of internal combustion engine liner surfaces after long use are given in Figs. 3 and 4. Fig. 3 is typical of a soft, coarse-grained cast-iron, containing large graphite plates. The hard phosphide areas are to be seen distinctly outlined in relief. The curious appearance of the graphite plates as white worm-like forms is characteristic, and is ascribed to the reflection of light by the polished graphite surfaces as contrasted with the dark appearance of the surrounding metal.

FIG. 2. MICRO-SECTION OF FIG. 1—UNETCHED; MAGNIFIED 250 DIAMETERS.

FIG. 3. MICRO-PHOTOGRAPH OF WORN SURFACE LINER; UNETCHED.

FIG. 4. MICRO-PHOTOGRAPH OF WORN LINER SURFACE; UNETCHED; MAGNIFIED 200 DIAMETERS.

Fig. 4 is typical of a very close-grained cast-iron. The hard phosphide constituent appears very distinctly in relief, assuming a distinctly net-like form of distribution. In the background can be seen numerous small dark holes representing disintegrated material. Under high powers in grey ferritic cast-irons the ferrite grains are also outlined, and the laminæ of the pearlite can often be distinctly traced.

Cast-iron as a whole is a conglomerate of a number of constituents, ferrite, pearlite, cementite, and phosphide eutectic, of widely different mechanical and physical properties, the soft and ductile ferrite and pearlite on the one hand, and the extremely hard and brittle phosphide eutectic and cementite on the other hand. The whole of the grains constituting the mass are more or less separated by numerous graphite plates, resulting in the mass having a very low intercrystalline cohesion.

In the engine cylinder, under the influence of the abrading action of the piston rings, together with the slight initial surface disintegration brought about by the stresses resulting from the reaction of the connecting rod, a certain amount of detached material is produced which becomes powdered and suspended in the film of oil.

This suspended material, under the influence of the reciprocating motion of the piston, is undoubtedly responsible for the relief polishing of the surface of the cylinder, resulting in the harder constituents, usually the phosphide eutectic or the cementite, projecting above the surrounding material.

Eventually these projections, together with the other grains composing the surface of the cylinder, under the influence of the abrading action of the piston rings and the vibratory stresses produced by the motion of the piston and the reaction of the connecting rod, are loosened and subsequently detached, a procedure which is no doubt facilitated by the increased temperatures and gas pressures inside the cylinder.

Such is, in all probability, the mechanism of surface disintegration in engine cylinders.

Surface Flow Phenomena.—It has been well known to engineers for a long period that with cast-iron parts which are subjected to the influence of rubbing actions, such as, for example, engine cylinders, slides, &c., immediately such parts have been in use for a sufficient length of time to have acquired a peculiarly-glazed surface or glazed appearance, then satisfactory working of those parts is obtained.

The cylinder walls of high-speed engines, after having been in running for a considerable period, are harder, and become increasingly difficult to file, and the raised markings left on the cylinder walls after a "seizure" has taken place are often glass hard and incapable of being filed.

The glazy appearance produced on cast-iron liner surfaces after a period of running is undoubtedly very important and plays a large part in the reduction of the extent of wear and in the efficiency of its anti-frictional properties. Our Continental neighbours would appear to have realised this, and it is believed that some of the large Continental gas-engine manufacturers subject their gas-engine liners and pistons to a period of running in the engine, previous to putting the engine in work. The object of this procedure is undoubtedly to bring about the production of this glazy appearance.

It is very probable that this glazy appearance is the product of a number of different causes. The most important one appears to be that under the influence of alternating stresses brought about by the motion of the piston the surface grains are deformed by being broken

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down along the slip planes, ultimately producing a surface of very fine crystal structure. Micro-examination of such surfaces reveals in many instances very finely granular structures even at high magnifications. Such surfaces are harder, and will be obviously far less sensitive to the effects of surface disintegration than the original coarser-grained structure. In addition, owing to the increase in the number of crystal boundaries, the total effect of intercrystalline cohesion is enormously increased, and whether this enhanced strength noted at the crystal boundaries is due to the influence of the presence of amorphous cement or surface tension or both, such superficial layers on liners must be enormously strong. The presence of the elements manganese and chromium in notable quantity undoubtedly increase the resistance of cast-iron to wear. This is due to the production of these deformed surface layers, which are readily produced in such irons.

The microphotographs Figs. 5 and 6 show a layer of hard matter resulting on a gas-engine liner surface after a seizure. The flowing of the layer over the machine tool marks is well illustrated in Fig. 6. On etching such a layer the hard areas of the phosphide eutectic are

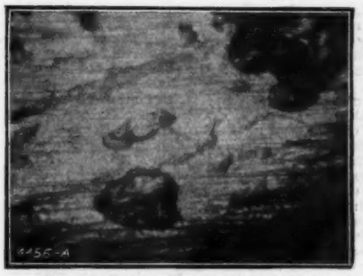


FIG. 5. UNETCHED; MAGNIFIED 150 DIAMETERS.

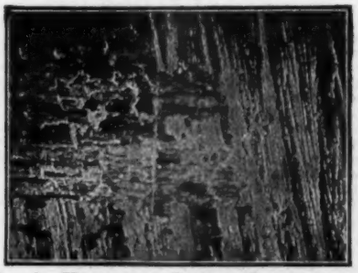


FIG. 6. UNETCHED; OBLIQUE ILLUMINATION; MAGNIFIED 30 DIAMETERS.

FIG. 7. ETCHED WITH 1.2 HNO_3; MAGNIFIED 150 DIAMETERS.

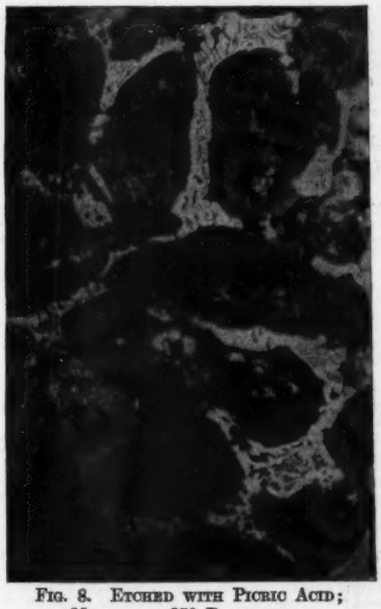


FIG. 8. ETCHED WITH PICRIC ACID; MAGNIFIED 250 DIAMETERS.

revealed embedded in the surrounding darker layer, Fig. 7. The numerous white specks also revealed are presumably particles of disintegrated phosphide eutectic The normal structure of this cast-iron, after grinding off the hard layer, is shown in Fig. 8. This will be seen to indicate a soft liner, containing large areas of primary ferrite.

The author considers that these layers consist of detached material which has been bodily deposited on the surface of the liner, either from the piston or displaced from some other portion of the liner. In all probability they consist of, in this instance, large ferrite areas which have been detached, and owing to their comparatively large size, and under the influence of the intense pressure, have "flowed" over the surface of the liner. It is very probable that the intense heat developed in this layer, owing to friction (which can actually be observed as a white heat) causes the rapid absorption of carbon either from the graphite or from the lubricant, or from both, resulting in the production, at this high temperature, of the hardenite solid solution. The cooling of this highly heated layer, in actual contact with the solid walls of the liner, is more or less rapid, and according to the degree of rapidity of the cooling, the type of structure and the degree of hardness presented by the layer is determined. On examination of these layers under the microscope, when etched, structures are revealed which are undoubtedly intermediate between hardenite and pearlite.

Similar effects are sometimes obtained during grinding operations on cast-iron. Under certain conditions, when the wheel is said to glaze, in the case of cast-iron this peculiar hard surface is produced. This is probably the result of surface flow in a like manner to that above.

Anti-frictional Properties.—It is a well-known fact that, apart from the wear of metals and alloys under actual rubbing contact, that certain metals and alloys exhibit a special property of undergoing this rubbing treatment in a more satisfactory manner than others. The extent to which a metal or alloy will undergo this treatment without overheating or seizing is to a large extent a property of the individual metal or alloy concerned, and this property for the purposes of this paper we designate its anti-frictional property. It must be understood that the load, and possibly also the speed under which the mutual rubbing action takes place, also have an influence on this property. For our purposes these influences are at present ignored and considered as constant.

Reference to the so-called anti-friction alloys affords an interesting analogy. These alloys are for the most

FIG. 9. SURFACE OF WHITE-METAL BEARING; UNETCHED AND UNPOLISHED; MAGNIFIED 48 DIAMETERS.

part constituted of such metals as tin, lead, copper and antimony, the proportions of which are so designed as to produce an alloy of such a character as to give the most satisfactory results from the point of view of overheating and seizure when in use as engine or line-shaft bearings.

Experience has shown that such an alloy should as a general rule consist of at least two constitutents of widely different physical properties, embedded in each other. When in actual use the surface of such a metal becomes polished in relief, and the harder constituents project above the surrounding matrix, producing a surface of an irregular contour. A micro-photograph of such a surface taken from a white-metal bearing in actual use in an engine is shown in Fig. 9. The white hard cubical crystals of, in this particular case, the chemical compound $SbCu_3$ are to be seen standing in relief.

It is considered that these hard projecting points serve as direct supports for the greater part of the load, whilst the minute hollows serve as minute reservoirs evenly distributing the oil over the whole surface.

In the high-speed engine cylinder the running properties of the material of which the piston and cylinder are constructed are subjects of great importance and demand wide recognition.

Primarily it is owing to its special properties in this respect that engine cylinders are constructed of cast-iron, and it is very significant that as yet we have no other material that will successfully replace cast-iron in this capacity. In addition, the limitations of cast-iron, both in respect of these properties and also the general mechanical strength properties, are a drawback to advance in high-speed engine design.

The general excellance of the anti-frictional properties of cast-iron is commonly ascribed to the lubricating qualities of the free carbon content. In a large measure this is quite true, though not *strictly* correct, and, indeed, when it is remembered that cylinder liners and pistons are in successful use for a number of years, the influence of the superficial graphite content is not sufficient explanation.

Exactly as is the case with anti-friction alloys previously mentioned, under the influence of the reciprocating motion of the piston, and the abrading action of the fine particles suspended in the oil, a surface of irregular contour is developed on the cast-iron, the harder constitutents standing in relief, as illustrated in the section on wear.

These minute hollows, together with the holes developed as a result of surface disintegration, serve as distributing reservoirs of the lubricant, ensuring efficacious and excellent distribution of the lubricant over the whole surface. It might also be mentioned at this point that the "glazy" surfaces presented by cast-irons after subjection to continuous motion are also an important consideration in this connection, although at present their influence is somewhat obscure (see "Hardness)."

(To be continued.)

THE PRODUCTION OF PIG-IRON AND STEEL IN CANADA IN 1916.

THE Dominion Department of Mines has received from the producers a record of the production of pig-iron and of steel ingots and castings during the first eleven months of the year 1916, which, together with estimates for December, show a probable production of pig-iron in Canada during the twelve months ended December 31, 1916, of 1,171,727 short tons (1,046,185 gross tons), and a probable production of steel ingots and direct steel castings of 1,454,124 short tons (1,298,325 gross tons), of which 1,423,485 short tons were steel ingots and 30,639 short tons were direct castings. The production of pig-iron in 1915 was 913,775 short tons, and of steel ingots and castings 1,020,896 short tons, showing an increase in the production of pig-iron in 1916 of about 28 per cent. and an increase in production of steel ingots and castings of over 42 per cent. The 1916 production was greater than that of any previous year, the second largest production of pig-iron having been 1,128,967 short tons in 1913, and of steel ingots and castings 1,168,993 short tons, also in 1913. The production in 1916 during the first six months and monthly during the last six months was as follows, in gross tons:—

	Pig-Iron.	Steel Ingots.	Direct Castings	Total.
	Gross tons.	Gross tons.	Gross tons.	Gross tons.
Six months ended June ..	501,872	577,099	11,715	589,714
July	82,154	101,178	2,284	103,462
August	78,450	108,889	2,299	111,188
September	91,736	116,828	2,524	119,352
October	101,436	126,577	2,924	129,501
November (partly estimated)	95,237	119,468	2,745	122,213
December (estimate) ..	95,300	119,930	2,865	122,795
Six months ended December	544,313	692,970	15,641	708,611
Twelve months „ „	1,046,185	1,270,969	27,356	1,298,325

Of the total production of steel ingots and castings in 1916, about 43,790 short tons (39,098 gross tons) were made in electric furnaces. In 1915 only 61 short tons were reported as having been made in electric furnaces.

PIG-IRON EXPORTS FROM THE UNITED STATES.—We read in the *Iron Age* that pig-iron exports in September were 64,122 gross tons, and in October 101,756 tons, both of these figures exceeding those for any previous month. To October 1, 1916, the total was 302,504 tons, against 156,939 tons to October 1, 1915, and 92,014 tons to October 1, 1914. Adding the October exports brings the total to November 1 to 404,260 tons, or 40,425 tons per month. In 1913, the record year, the monthly export rate was only 23,137 tons. The total to November 1, 1916, is 126,612 tons in excess of the total for the whole year 1913.

THE NAVY AND THE WAR.

ADMIRAL SIR JOHN R. JELLICOE, G.C.B., O.M., K.C.V.O., who was Commander-in-Chief of the Grand Fleet from the outbreak of war until about a month ago, when, on the reconstruction of the Government, he became First Sea Lord of the Admiralty, was presented on Thursday, the 11th inst., with the honorary freedom of the Fishmongers' Company. In his reply he reviewed the work of the Navy during the war, and urged on workers the vital importance of strenuous self-denying diligence and economy. We give Sir John's address in full :—

"I cannot express adequately my great appreciation of the high honour you have conferred upon me, and I would like to believe that you have thus distinguished me as a representative of that great Service to which I belong, and as a recognition, also, of the value of the work that has been done with so much of heroism and untiring vigilance as well as unfaltering patriotism by every officer and man of the Navy during these strenuous 2½ years. The Acting Prime Warden has enhanced the honour to me in drawing some parallel between the services of Lord St. Vincent and myself. I feel that I cannot claim comparison with that great man. We of this generation owe a great debt to the naval strategists of the past. I have studied with great profit and admiration their guiding principles of strategy, and have been influenced by the high devotion to duty of Lord St. Vincent and others who laid the foundations of Britain's naval greatness. There are great differences between the conditions of to-day and a hundred years ago. These lie in the greater speed of ships, in the longer range of guns, in the menace of the torpedo as fired from ships, destroyers and submarines, and the menace of mines, the use of aircraft as scouts, and of wireless telegraphy. In the Napoleonic era the ships opened fire with guns at ranges of about 800 yards; the ships of to-day open fire at 22,000 yards (or over 11 nautical miles) range, and gun-fire begins to be very effective at 18,000 yards. The torpedo as fired from surface vessels is effective certainly up to 10,000 yards range, and this requires that a ship shall keep beyond this distance to fight her guns.

As the conditions of visibility, in the North Sea particularly, are frequently such as to make fighting difficult beyond a range of 10,000 yards, and as modern fleets are invariably accompanied by very large numbers of destroyers, whose main duty is to attack with the torpedo the heavy ships of the enemy, it will be recognised how great becomes the responsibility of the admiral in command of a fleet, particularly under the conditions of low visibility to which I have referred; as soon as destroyers tumble upon a fleet within torpedo range the situation becomes critical for the heavy ships.

"The submarine is another factor which has changed the situation, as this class of vessel, combined with the use of mines, entirely prevents the close blockade resorted to in former days. In addition these two weapons add greatly to the anxieties of those in command. It is one thing to fight an enemy that you can see. It is a different matter to deal with a hidden foe. Thus modern conditions add immensely in this respect to the responsibility of those commanding fleets. They cannot get warning of the enemy being at sea until the enemy is well at sea. Nelson, watching Villeneuve off Cadiz, had his inshore squadron close into the enemy's port, and could see what was actually going on inside that port. The British fleet of to-day, watching the German High Seas Fleet, is not in the same happy position. The further the watching ships are from the enemy's port the greater is the facility with which the enemy can escape, and the greater is the difficulty of intercepting him. There was never any likelihood in the olden days of the enemy's fleet escaping unseen unless the blockading squadron was forced from its watching position by bad weather, which, of course, occasionally occurred. In our day submarines and mines compel the watching force to take up their station further and further away. In spite of this, and in spite of the German boast as to the occasions on which the German fleet has searched the North Sea for the British fleet, our enemies have only on one occasion ventured sufficiently far with their main fleet to give us an opportunity to engage them. No vessels, neutral or British, have sighted the High Seas Fleet far from its ports on any other occasion. It is true that on the 19th of August of last year the enemy's fleet came within measurable distance of the English coast, being sighted by some of our patrols, but turned back, presumably because the presence of our fleet was reported, perhaps by their aircraft. Raids on the British coast with fast cruisers or battle-cruisers have been carried out, but on each occasion the passage from German waters has been made apparently under cover of the night, the enemy appearing off our coast at dawn and retiring before comparatively small forces. Such feats were, of course, impossible in the days of slow speed, and are now undertaken probably only in the hope of enticing us into the adoption of a false strategy by breaking up our forces to guard all vulnerable points. I do not criticise the Germans for their strategy or for not running any risks with their fleet. On the other hand, their boasts of searching the North Sea for the enemy must be pronounced as without justifiable basis.

"The next point to which I would like to draw your attention has reference to the world-wide nature of the war so far as the British Navy is concerned. It is not perhaps always realised how far-reaching are our naval activities, and how great, therefore, is the call on our naval resources. It may be interesting to state that the approximate number of vessels of all classes which comprise the British Navy of to-day is nearly 4,000. This includes battleships, battle-cruisers, light cruisers, destroyers, submarine boats, mine sweepers, patrols, and many other miscellaneous craft, all of which are necessary for the effective conduct of a war of to-day. Our activities range from the White Sea, where we are doing our best to assist our gallant Russian allies, past the North and South Atlantic, where cruiser squadrons are at work, on to the far Pacific, where we are working in co-operation with our gallant Japanese allies. In the Mediterranean, the Navy took no inconsiderable part in the Dardanelles campaign, assisted by our gallant French allies, and is now working with both the French and Italian Navies in connection with the Balkan campaign and in the Adriatic. On the West Coast of Africa the Navy played a useful part in the fighting in the Cameroons. On the East Coast of Africa the naval forces, including our river gunboats, monitors and aircraft, have rendered great service to our kinsmen from the Union of South Africa. In the Persian Gulf and up the Tigris River numerous river gunboats and other vessels are assisting our army in the Mesopotamian campaign. Our East Indian squadron, which is working from Port Said through the Canal and Red Sea, is helping the army of Egypt and safeguarding the communications with India, and thence to far-eastern waters. In the early days of the war the Navy was pleased and honoured to work along with our Japanese allies in the capture of Kiau Chow. In fact, it may be said that there is no part of the world where the Navy has not duties and responsibilities in connection with this war. And I might draw attention to the arduous and continuous work of the cruiser squadron in home waters, which is mainly engaged in preventing supplies from reaching our enemies. Ships are intercepted and boarded in great numbers under every condition of weather. Some idea of the work may be gathered from the fact that, on an average, 80 ships per week are intercepted and examined on the high seas by the vessels of this squadron.

"The task of keeping the enormous mass of ships working in all parts of the world, of supplying them with fuel, munitions, &c., can only be recognised by those in possession of all the facts. The work, too, involves a great effort on the part of the mercantile marine. Without our mercantile marine the Navy, and, indeed, the nation, could not exist. Upon it we have been dependent for the movement of our troops overseas, over seven millions of men having been transported, along with the guns, munitions and stores required by the army. The safeguarding of these transports, both from the attack of such service vessels as have been at large and from submarine attack, has been carried out by the Navy. We have had to draw also upon the *personnel* of the mercantile marine, not only for the manning of the transport ships, but also very largely for the manning of the whole of our patrol and mine-sweeping craft. Nearly 2,500 skippers being employed as skippers, R.N.R.; the number of R.N.R. Executive Officers has increased almost fourfold since the outbreak of war. Indeed, it is impossible to measure fully the debt which the country owes to our mercantile marine. In the old days it used to be said that there was jealousy between the mercantile marine and the Royal Navy, but whatever may have been the case in the old days, there is no room now in the Navy for anything but the most sincere admiration and respect for the officers and men of the mercantile marine. I think I know sufficient of those officers and men to believe that the feeling is reciprocated. Those of us who have been closely associated with the officers and men who man our armed merchant vessels and patrol craft have realised from the first day of the war how magnificent were their services, how courageous their conduct, and how unflinching their devotion to duty under the most dangerous conditions. The value of the services of the officers and men of the mercantile marine goes also far beyond their work in armed vessels. When one thinks of the innumerable cases of unarmed ships being sunk by torpedo or gun-fire far from land in a heavy sea, with the ship's company dependent alone upon boats for their safety, one is lost in admiration of the spirit of heroism of those who not only endure dangers and hardships without complaint, but are ever ready to take risks again and again in repeated voyages in their ships.

"The submarine menace to the merchant service is far greater now than at any period of the war, and it requires all our energy to combat it. It must and will be dealt with; of that I am confident. But we have to make good our inevitable losses, and in order to do this we are dependent upon the shipbuilding industry of this country. The munitions organisation has done a great work for the output of munitions; it now remains for the shipbuilders and marine engineers to rival that work. The first essential is the wholehearted co-operation of the men in the shipbuilding yards and in the engineering workshops. In the same way as Sir Douglas Haig has appealed to the munition workers to give up holidays and to devote themselves to the supply of those munitions which are essential for the safety and success of their comrades in the trenches, I now appeal to the men in the ship-yards and engineering shops to put forth their best efforts continuously and ungrudgingly to keep up the strength of our mercantile marine, and to provide those gallant fellows, who have gone through innumerable dangers and hardships when their ships have been sunk, with new vessels with which to carry on the transport of the necessary supplies of food and material for the manhood and the industries of the country. Let there be no question of strikes, no bad time-keeping, no slacking, but let masters and men remember how great is their responsibility, not only towards the Navy and the nation, but also towards our Allies.

"Before I leave this subject may I presume to remind the big shipping companies of the privilege which is theirs to see that some provision is made out of the war profits for the wives and children of those gallant fellows who have given their lives for their country when their ships have been sunk, as truly as those who have lost their lives in the battle line. It is not for me to make suggestions, but I venture to say that the hearts of the officers and men would be lightened in the continued presence of danger and the recurring possibilities of disaster if those they may leave behind them would be cared for and educated.

"In this hasty survey of the naval side of war I have not as yet said a word on the point which is really nearest to my heart, and that is the subject of the spirit of the officers and men of the fleet of which I have so recently given up the command. During two and a half years of war the endeavour to keep that fleet at a high pitch of efficiency has necessitated strenuous and unceasing effort on the part of everyone connected with the fleet, either afloat or ashore. I said at the outset of my remarks that conditions affecting naval warfare differed to-day from those of a hundred years ago. That applies almost exclusively to matériel, and is due to the advance in applied science, which has brought vast progress, almost revolutionary change, to the Navy, as to other departments of activity. In some cases these changes can be commended if war is the only means of settling differences; in other respects they are reprehensible, and have been wantonly used by our enemies. There has, however, been little change in our men, except in the development of higher principles and in fuller recognition of individual responsibility in the national cause. The spirit of our forefathers lives on in all its vigour and devotion to King and country in the officers and men of to-day, with this added, that there is a higher standard of personal worth, of mental alertness and of moral rectitude. No one could ask for a finer *personnel* than we have in the Navy. Education has enabled every man to arrive at a just appreciation of the justice of our cause, and to conduct himself as becomes a man fighting for the freedom of the smaller nations and for the liberation of humanity from the threatened thraldom of military slavery. Can there be any doubt of the issue when this fundamental belief is associated, as it is, with all-pervading patriotism and unflagging zeal to accomplish the end we and our Allies have in view? Every man in the Navy is eager and prepared to do his duty. He asks, and he is entitled by his services and sacrifices to ask, that the nation shall do its part by working with equal self-denying diligence as are our soldiers and sailors, so that there may be provided that great variety and enormous volume of material which is required for the fighting forces, and that all men and all women shall by practising strict economy render possible the maintenance of adequate financial sinews of war. If we all do our part, all will be well with us. Of one prominent fact I can speak with full confidence born of experience—the nation can depend on the Navy being ready, resourceful and reliable."

THE SHIPBUILDING INDUSTRY IN DENMARK.—In a survey of the past year in a Danish paper, Mr. Ivar Knudsen, director of the Burmeister and Wain Shipbuilding Company, gives the following short account of Danish shipbuilding during 1916. As regards the conditions prevailing within the shipbuilding industry during 1916, it may be said that the yards, on the whole, have been very fully employed, especially with repairs. In the matter of new vessels the year, especially in the latter portion, has not been successful. All yards have orders in hand for long periods to come; in the beginning of the year the supply of materials was fairly satisfactory, but the supplies, by degrees, grew smaller and smaller, and have now dwindled down to practically nothing. Danish delegates have been to Berlin to negotiate concerning export dispensations for shipbuilding material, but whether these negotiations will lead to a result so that Denmark will receive the necessary quantities of steel and iron has not yet transpired. Should the hopes in this connection fail, the result will be a stoppage of all work in the building of new vessels, and repair work only can be proceeded with.

THE RUSSO-GERMAN ELECTRICAL COMPANIES.—At a recent meeting of the Russian Special Committee for Fighting against German Preponderance, means were discussed for ousting the German influence of the following companies :—Siemens and Schuckert, Siemens and Halske, Allgemeine Elektricitäts Gesellschaft, The Elektro Peredatscha and The St. Petersburg Company for Electric Lighting of 1886. The representative of the Minister for Commerce proposed three measures for the attainment of this end, viz., liquidation, purchase by the State, or participation of the Government in the companies by exercising the requisite control. The committee pronounced in favour of the first measure and of liquidating all five companies, including the Petersburg Company of 1886. A detailed plan for liquidation will be worked out by the liquidating boards which were to be appointed, but the committee has already drawn up some general regulations. According to these, all shares not issued to a distinct person have to be exchanged for shares issued to a named person; the owners of the present shares have the right to record their shares with a view to such exchange, but such exchange can only be granted to persons with regard to whom there can be no suspicion as to German capital being implicated. The other shares (that is, the shares held by Germans or in which German capital is interested) will be purchased by the Russian State at their nominal value. These shares will then either remain in the possession of the State, whereby it will become directly interested in the different concerns, or they will be sold by the State. According to the plan, the liquidation of all the five companies should be completed by July 1, 1917.

WORM GEAR AND WORM GEAR MOUNTING.*

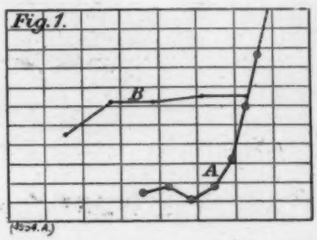
By F. W. LANCHESTER, M.Inst.C.E.

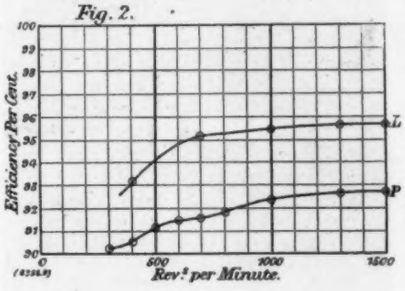
INTRODUCTION.

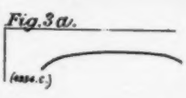
IN a paper read before this Institution in 1913† the author dealt with the subject of worm gearing broadly, and more particularly with the Lanchester Worm Gear, which was the first to be successfully introduced in automobile practice. It is, perhaps, unnecessary here to recapitulate the distinctive features of worm gear of different types. It is enough to say that at the present time there are, broadly speaking, two types of worm gear in competitive employment—the Lanchester gear, which may be spoken of as a variant of the Hindley worm, and the cylindric, parallel, or straight worm such as that marketed by Messrs. David Brown and Co., Messrs. Wrigley, and others, which may be taken as a development of the ordinary worm gear in common use by engineers for a century or more. Although on the one hand the Lanchester gear is described as a form of Hindley, and the parallel or cylindric worm as that of ancient practice, such descriptions do not entirely do justice to either the one or the other. Worm gear for power transmission (where mechanical efficiency is the talisman of success) is a comparatively modern development, and the gears used to-day in motor-car transmission and in other cases of power transmission, such as electric lifts, hoists, &c., bear but a very faint resemblance to their forerunner, which was designed and used for motion transmission alone. Indeed, it is correct to say that in the more ancient applications of worm gear a common condition was that the drive should be irreversible; in truth, it was when such drive was wanted, as in a hand winch, that the engineer turned his thoughts to the worm wheel as a solution. It is a point of importance that so long as this irreversibility is a condition the mechanical efficiency as a power transmitter cannot exceed 50 per cent. We may therefore take it that although it may be difficult to draw a hard and fast line between the worm gear of old and the worm gear of to-day, there is, from the practical point of view, as complete a break of continuity as if such a hard and fast line existed.

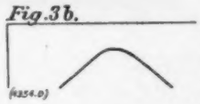
Thus, in the case of motion transmission‡ it was uncommon for worm gear to have an efficiency higher than 30 per cent. or 40 per cent.; but immediately the problem is changed to that of economic power transmission and the engineer concentrates his attention on the question of mechanical efficiency, a duty as high as 94 per cent. or 95 per cent., or, as shown in the previous paper, even 97 per cent., is to be obtained.

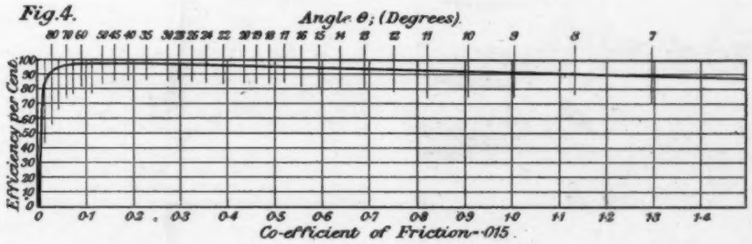
In the previous paper the question of efficiency was made the pivot point of the discussion, and the result of the tests made by the staff of the National Physical Laboratory at the Daimler Works were freely used in the body of the paper, the particulars of the tests (with the National Physical Laboratory report) being given as an Appendix (Appendix I). Incidentally, in criticism on the practical side of his experience in association with Messrs. David Brown and Sons, as the makers of power transmission worm gear of the parallel type, in a written communication to the paper. Mr. Kerr-Thomas also contributed a written communication, in which he expressed disagreement with some of the author's conclusions. These contributions were dealt with in detail by the author in his reply, but they appear to indicate considerable misapprehension as to some of the fundamental facts connected with worm-transmission design, and to some degree the present paper may be taken as directed to clearing up these points of controversy more definitely than was attempted in the earlier paper, and to demonstrate in an irrefutable manner some of the essential differences which result in

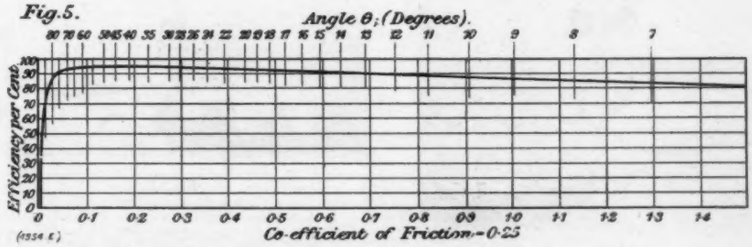












that paper particulars were given of the author's dynamometer, by which the said tests were made, and by which a far higher degree of accuracy was obtained than has ever been previously certified. In that paper also was discussed the theory of worm gear efficiency by the author's methods. Much of the matter was criticised severely in the discussion by Mr. F. J. Bostock, who not only challenged the theoretical work, but also the comparative test results as between the parallel and Lanchester types of worm. Mr. Bostock based his criticism on the practical application of the two systems of gear cutting.

In the previous paper the maker of the particular parallel gear which was tested in comparison with the Lanchester was not stated; it might have been considered unfair to have named the gear when the maker would have no chance to ascertain or satisfy himself that the best possible had been done with it. In the present paper the maker of the gear of parallel type which has been used as a comparison is definitely given, it is the gear of Messrs. David Brown and Sons, obtained direct from one of their customers. It is presumably a fair sample of the gears supplied by that firm. It is, of course, much more satisfactory to be able to state the maker of the gear which has been subjected to investigation, and the writer therefore has had no hesitation in taking up the gauntlet thrown down by Mr. Bostock.

The present paper naturally divides itself into two parts; the first part relates to a detailed discussion of the theoretical side of the subject, and may be taken as supplementary to the discussion of the previous paper, the second part relates to a practical examination of the "solid geometry" of worm gear by a new method, and is in fact a detailed comparison of the Hindley and parallel types of worm gear as exemplified in the Lanchester and David Brown respectively.

A third section of the paper is devoted to the question of worm gear mounting or housing, a feature in which the practice in respect of the two types does in certain respects present differences.

PART I.

There are a great number of variables—an inconveniently great number of variables—in the design of worm gear upon which its efficiency depends. Without digesting the problem the factors are very numerous; there are thus the diameters of the worm and the wheel and the gear ratio, also the velocity of rotation, and the torque or the horse-power transmitted (either may be specified). Beyond this there is the degree of approximate contact between the pressure surfaces, and there is the question of lubrication. The author's theoretical treatment is based definitely on the fact that the first group of variable factors, namely, the diameters of worm and wheel, the gear ratio, the revolution speed and torque transmitted, can all be represented from the point of view of efficiency in the one quantity, the pitch angle of the tooth and an assumed constant angle or coefficient of friction. For any set of gear between wide limits of load and speed the angle of friction is in fact almost constant, quite near enough so for the purposes of the foundation theory. On this assumption (i.e., angle of friction = constant), it is then easy to demonstrate that the efficiency will be constant for all variations of torque and speed, also that the efficiency is independent of the diameters of the gears provided that the pitch angle of the teeth is the same. The approximate truth of this as an experimentally established fact is the justification of the method, and this has been fully established by the National Physical Laboratory tests and report.

In Fig. 1 is reproduced Fig. 42 from the previous paper, in which a comparison is given between one of the tests from the National Physical Laboratory report and one of the so-called tests of a parallel worm cited by Mr. Kerr-Thomas, namely, from a paper by Professor Kennerson. Here, B, we see the National Physical Laboratory test of a Daimler-Lanchester worm in which from about 27 to 62 h.p. the efficiency does not vary more than one-third of 1 per cent., whereas in the plottings from Professor Kennerson's paper, A, there is a curve which ranges from 35 to 65 h.p. over a variation of 8 per cent. Now in the results taken with the author's dynamometer, which is certified by the National Physical Laboratory to be true within one-fifth of 1 per cent. (1 in 500) and is probably ordinarily within 1 in 1,000, a considerable range of load was found in every case, over which the efficiency was virtually constant, both in the Lanchester and parallel types, and similarly the efficiency was also virtually constant over a considerable range of speed, though here the variations were, perhaps, somewhat greater. The author showed that there is every reason to suspect the accuracy of Professor Kennerson's results, and at the outset the results of the National Physical Laboratory tests are taken as showing that this approximate constancy of the efficiency over a certain working range for any given set of worm gear is an established fact.

The author's own tests (on his dynamometer) of worm gear of the parallel type show clearly the same characteristic feature, namely, the approximate constancy of the efficiency over a considerable range of velocity. Two typical curves are given in Fig. 2.

There are two conditions under which it would appear that the efficiency invariably shows a falling-off: firstly, when the load per tooth for any given pair of gears exceeds a certain value, the other is when the tooth-rubbing velocity is less than a certain value; also there is, without question, a falling-off in the opposite extremes if a sufficiently great range of speed or load be investigated. Otherwise the approximate constancy of the angle or coefficient of friction may be taken as established. It is evident that the constant condition corresponds to the minimum value of coefficient, or conversely the maximum of efficiency. In the nature of things, where A is a function of B, A is approximately constant in respect of B when A is a maximum and when A is a minimum. This is as commonly expressed in the equation for maximum or minimum value as $dA/dB = 0$. Thus there is nothing extraordinary in the fact as stated. Its importance from the point of view of the theory of worm gear efficiency lies in the fact that the maximum is rarely, if ever, found to be a "peak," it is rather a "tableland," it is of the type shown in Fig. 3a, rather than the type shown in Fig. 3b. It is a further point of importance in connection with the theory of worm gear that the practical range of usage over which efficiency is important does not carry us into the regions where the higher coefficients are met with. Indeed, it is actually the increase of the coefficient and falling off in the efficiency under excessive load that determines sharply the maximum load limit to which any given pair of gears may be subjected, for a very moderate increase in coefficient above its normal "least value" results in, or is evidence of, the partial breakdown or rupture of the lubrication film and the disintegration of the gear. This is the case, whether it be of the Lanchester or parallel type; in fact the increase of the coefficient under heavy loading is the first sign of incipient lubrication failure, and so the point of fall in the efficiency curve under heavy loading may be taken as an invariable indication, in the comparison of any two pairs of gear, of their relative higher load limits.

In engineering practice we are accustomed to meet

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* Paper read before the Institution of Automobile Engineers on December 13, 1916, slightly abbreviated.

† See Proc. I. A. E., vol. vii, page 215.

‡ The distinction between motion transmission and power transmission is arbitrary, since in every case a transmission of power takes place, even though in small degree. It is the object in view which is the distinctive circumstance, and whether or no mechanical efficiency is a point of importance.

problems in which the coefficient of friction is legitimately treated as constant; in all these problems certain actual variations exist, but the underlying fact is so nearly true that the basic theory is correctly founded on the assumption of a constant coefficient of friction, and such changes as are met with are considered as variations from this constant value rather than in relation to the zero. The tests published in the author's previous paper fully establish the fact that power transmission worm gear comes legitimately into the group of such problems, though it was by no means certain prior to the paper that this was the case. If such results as those of Professor Kennerson were true, we should not be justified in basing any arguments on the constancy of the frictional coefficient, and the foundation of the theory of worm gear efficiency would consequently become far more complex and difficult than is actually the case.

So far we have dealt with the group of factors which determine the efficiency as based on the coefficient of friction: in other words, we have confined our attention to the group of variable quantities which suffice to determine the efficiency once the angle of friction is stated, and have seen that these are summed up in the one quantity, the pitch angle. It is clear that the assumption of a constant angle of friction simplifies matters to the utmost possible extent, for in place of the multitude of different variables we have only to consider the pitch angle of the tooth, that is, the angle relatively to the worm axis—all the quantities on which this angle depends are then accounted for. The efficiency is given by the simple graph as in Figs. 4 and 5.*

The other half of the problem is to deal with the factors on which the constant or minimum coefficient of friction for any given pair of gears depends, and more broadly the factors on which the extent of the approximately constant range depends, for it is the extent of this range in the direction of high loading which determines the maximum output capacity at any given speed of a pair of gears, and so determines their commercial value as an engineering asset.

The commercial value of high power-transmission capacity from an automobile standpoint may be regarded as even greater than from an engineering standpoint, for the importance of weight-saving is paramount. Thus, if two sets of gears, one of 8-in. and another of 10-in. centres, were to possess the same horse-power capacity for a given revolution speed, and even (owing to a difference of design or material) were to cost the same, one might be justified in considering them equally favourably in any ordinary engineering problem, but if the 8-in. centre gears weigh proportionately less than the 10-in. centre set, they will be far more valuable and a more saleable article from the point of view of the automobile constructor and user.

The efficiency curve in any case is of the type represented in Fig. 3*a*. At very light loads the efficiency may be poor owing to the fact that oil is being churned in the gear and churned in the bearings, since the power so consumed is virtually independent of the load. On the other hand (as already pointed out), the efficiency curve falls at heavy load owing to the thinning and incipient breakdown of the lubricating film.

It has been regarded as open to question to what extent the magnitude of minimum coefficient (maximum efficiency) is controllable; the author has found evidence of considerable variation according to the type of gear and lubricant. If it were not controllable, then the maximum efficiency for every individual pair of gears under the most favourable conditions would depend definitely upon the pitch angle of the tooth, and would be the same whether the gear is of the parallel or Lanchester type.

It has also been regarded as an open question whether the breadth of the "tableland," if one may say so, of the efficiency curve can be increased. Thus it might be argued that if, by obtaining better proximate contact (by any means) the breaking-down of the lubrication could be persuaded to take place at a higher tooth load, this same greater proximity of the tooth surfaces may result in a higher viscous churning resistance, and so take off in the range of coefficient at one end what it puts on at the other.

Although the author is prepared to take a liberal view and say that these points are open to controversy, opinion, as based on present-day experience, is decidedly that a better type of tooth contact corresponds to an absolute lower minimum coefficient—probably due to a thickening of the oil film,† and that this does not of necessity add to the churning loss, and thus the improvement results in an absolute broadening of the top of the efficiency curve, that is to say, an increase both in the maximum efficiency and in the range over which there is no sensible falling-off.

But the benefit of obtaining high tooth loads by improving the proximate contact of the tooth does not depend intrinsically on an actual increase in the range. Even if what be gained at one end be lost at the other, the result of improving the proximate contact of the teeth (by whatever means accomplished) is to enable a given pair of gears to transmit a higher standard of loading. Conversely, for a given horse-power transmission a smaller and lighter set of gears may be employed, with (*a*) a saving of money in material and machining, and (*b*) a saving of weight in the gears themselves and in the mounting, with a consequent better performance of the car, and, due to the reduction in the unsprung weight, less wear and tear on the tyres, &c.

We therefore realise that the essence of power transmission worm gear for automobile purposes is to be sought in achieving the highest tooth load compatible with the maintenance of the oil film and the approximate minimum coefficient of friction; any and every improvement in the area of proximate contact of the tooth surfaces in engagement with one another will be reflected in a bigger output from a given pair of gears and a reduction in the size and weight of gears for a given performance. It is one of the main objects of the present paper to examine the differences and relative merits of the Lanchester and parallel types of worm gear in this respect.

The advantage of reducing the centres and diminishing the size of a pair of gears for any given automobile is not only a matter of weight saving, important though this may be; it is equally a matter of compactness of design. It is and has been one of the difficulties in the application of worm gear to the back axle that if the worm be arranged beneath the wheel the ground clearance is jeopardised, and if it be arranged above the wheel the body clearance has to be cut fine. The result of experience appears to show that for the home market the question of ground clearance is the less important; a full size touring car with 35 in. driving wheels and a worm gear of 6-in. centres can be designed to give an 8-in. clearance in the centre of the rear axle, and this has proved itself ample for use in the British Isles, where consequently the underneath worm is widely used. It must be remembered that a clearance of 8 in. on the rear axle is as good as a clearance of, perhaps, 12 in. or more under the body of the car, since the body clearance has to allow for longitudinal undulations of the road as well as lateral, with an additional allowance for spring deflection.

It has been reported from colonial sources that the worm underneath is objectionable as not providing sufficient clearance. The author is doubtful whether this objection is generally valid; the same objection once carried weight in commercial circles with regard to the home market. It seems incredible, with the wheel base now accepted, some 11 or 12 feet or more, that if a clearance of 12 in. is required under the axle, anything less than 18 in. or 20 in. can be sufficient under the body of the car. Apart from the mere question of actual clearance, a contact between the road or chance boulders and the flywheel or base of the engine is liable to prove far more serious than the contact of the comparatively robust housing of the worm gear. However this may be, the objection exists, and has been sufficiently strong to induce many of our constructors when adopting worm gear to place the worm above instead of below.

When the worm is placed above the axle the question of body clearance gives trouble. Now the fashion, at least for the home market, is to keep down the floor level as low as possible—a "pleasure" car with a high floor level and centre of gravity is to-day unsaleable, in the author's opinion rightly so. The result of this is that where cars have the worm placed above the axle it is often found necessary to gouge a piece out of the rear body and fit a casing which protrudes through the rear body floor in order to provide the necessary clearance.

Beyond the above, the cooling of the worm box with

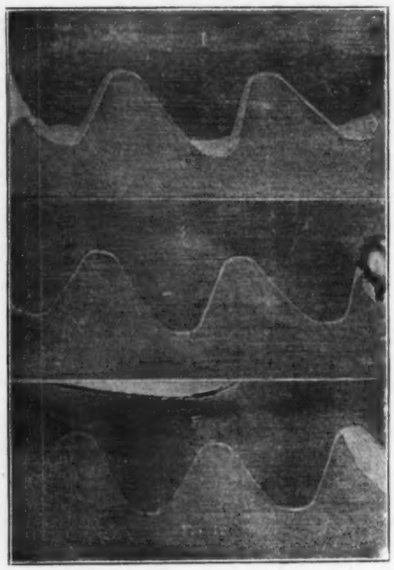


FIG. 6.

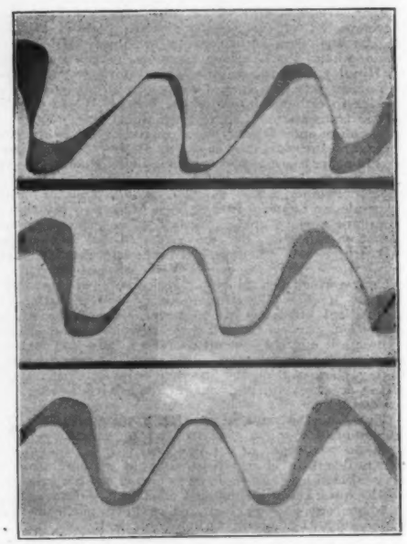


FIG. 7.

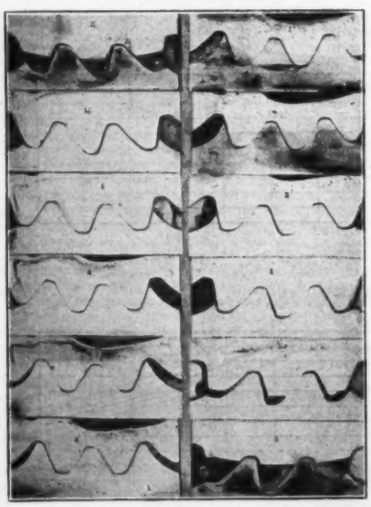


FIG. 8.

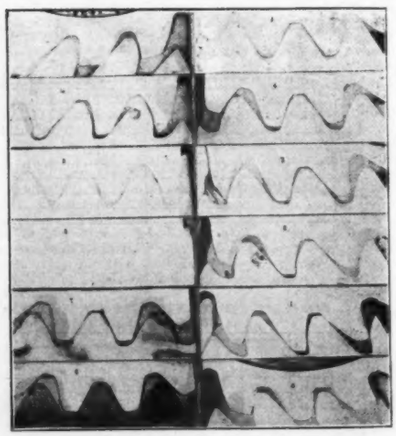


FIG. 9.

* Similar graphs were given in Figs. 4 and 5 of the earlier paper. The same blocks have not been employed; the originals were marred by faulty draughtsmanship. Compare the author's "Aerodynamics" (Constable & Co.), ch. ix, pp. 296 *et seq.*

† Over the load-bearing area.

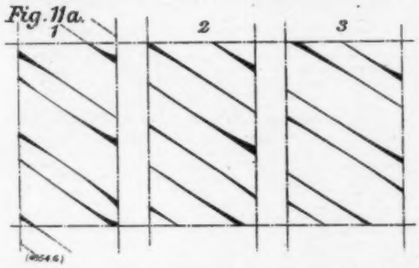
the worm on top is inferior to what it is when the worm is placed underneath; the actual importance of this point depends upon the general design of the car.

There is thus every inducement, apart from the already important consideration of weight, to endeavour by all possible means to obtain the maximum horse power or torque transmission capacity from a gear of any given size.

PART II.

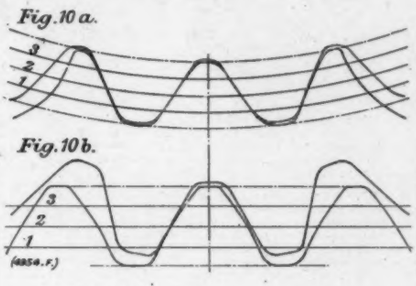
It has been shown that in worm gears of different types the efficiency depends upon two factors, the pitch angle of the teeth and a constant—the coefficient of friction. In the work done with the author's dynamometer it has been made abundantly evident that the constant, the coefficient of friction, has a different value in different cases; it is liable to slight variation in almost every different pair of gears tested, but the variation only becomes marked when the type of gear as determined by the system of cutting differs, as for example, in the case of gear of the Lanchester or Hindley type when compared with gear of the ordinary parallel type. Now the reason for these variations has never been thoroughly investigated, and may have appeared to be somewhat obscure; the author has, however, expressed views on the subject from time to time. Briefly stated, the author's suggestion has been that the value of the coefficient is affected by the degree of proximate contact of the teeth and the consequent variation in the thickness of the oil film*—the thicker the oil film the lower will be the coefficient of friction. Although this view has been advanced with a more than plausible show of reason, there has hitherto been no actual demonstration offered in proof, and it can scarcely be said to have obtained universal acceptance.

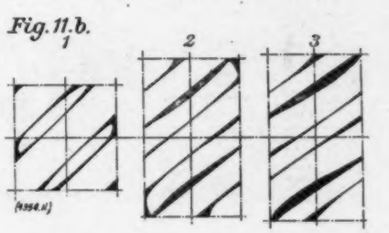
It would be possible in the case of the parallel gear to determine as a matter of pure geometry the extent of the clearances and the radii of curvature of the surfaces in contact at different point on the worm and wheel teeth where in engagement, and in fact in some degree this has already been done. It is conceivably possible that the same method might be used in the case of the Lanchester gear, but it would be extremely tedious and difficult, and at the best somewhat uncertain. For the purpose of the present paper it has been thought preferable to arrive at the result in both cases by actually dissecting a set of gears and reproducing the teeth form to an enlarged scale by photographic means. From the photographs so obtained it has been found possible to prepare drawings showing the curvature at the engagement surfaces along the path of motion, that is to say, more or less nearly normal to the plane of the photographic section.

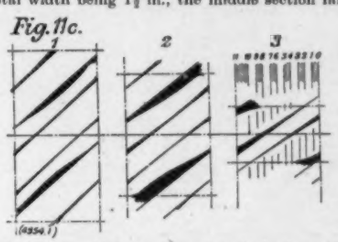


The initial problem of cutting and preparing the worm gear sections has presented certain difficulties of a minor character. In the first place means had to be taken to ensure that the gears were fixed in their relatively correct running positions, not only before the dissecting of the gear, but as concerning the resulting portions or slices; the worm and wheel had to be so secured that they would be in no risk of losing their relative positions during subsequent handling. For this purpose the gears were mounted in a jig at the correct centres, and in proper engagement, and the whole of the gear teeth in the region of engagement were thoroughly grouted with solder. The next process was to cut away the portion of the gears in engagement, and then to slice these up in a milling machine into section of uniform thickness. In order to avoid unnecessary sectioning, both faces of each slice were photographed as representing sections, and the thickness of the slice (¼ in.) was made the same as the thickness of the saw used in the cutting operation. In order that the photographs should read correctly, that is to say, so that they should be readily intelligible, the alternate numbers were reversed photographically, so that instead of the views being from alternately in front and behind the gear wheel, as is actually the case in examining the sections themselves, the photographs given in the plates illustrating the paper represent a series of sections one behind the other, all viewed in one direction.

There was some little difficulty experienced in obtaining a satisfactory process of etching in order to display the difference between the worm and wheel and the solder matrix. An attempt was made to use zinc in place of solder and then to act on the polished surface with sulphuretted hydrogen or sulphide of ammonia. It was hoped by this means to bring out the zinc as a white ground on which the darker copper and iron sulphide would appear black in contrast. It was, however, found too troublesome, if not impossible, to get the zinc to run properly and uniformly between the two surfaces. Several other methods of etching and polishing were tried—an example of these is given in Fig. 6. Ultimately the method used was to etch the surfaces with stannous chloride, $SnCl_2$; under this treatment the worm and wheel appeared white on a dark background, as in the photographs given on page 44. Figs. 6 and 7 give sample photographs of sections, Lanchester and D.B.S. respectively, to an enlarged scale. In Fig. 8 is presented a full set of twelve sections, numbered 0 to 11 inclusive, illustrating the degree of proximity of the surfaces in a pair of Lanchester gears, 6-in centres, 8/33 ratio. It will be noted that over the engagement portion of the surfaces the thickness of the matrix interspace is nowhere more than a fraction of a millimetre. The large masses of matrix visible at the end of the section and at the top of the teeth in the terminal sections numbered 0 and 11 are in each case beyond the range of the engagement region. Similar photographs [somewhat lost in reproduction] are given in Fig. 9 for the parallel worm gear made by Messrs. David Brown and Sons, 4½ in. centres, 5/21 ratio. A comparison between the two figures leaves no room for doubt as to which form of gear provides the greater proximity of contact.







The point of view of the photographs, however, does not give as clear an impression of the form or of the contiguity of the contact surfaces as might be wished; in order more fully to realise the type of the contact as defined by the difference in the radius of curvature of the two surfaces in their direction of relative motion, a development is required, in the case of the Lanchester the surface being one of double curvature. Any such development is of necessity a matter of convention—a convention involving some degree of distortion.

In the present case the construction adopted has been to take a number of concentric sections, three in all, one on the centre of the tooth height or pitch line, and one at one-quarter and one at three-quarters of the tooth height respectively; the reconstruction has been made in Fig. 11*a*, representing the Lanchester gear, and Fig. 11*b*, representing the parallel type. Since it is not the absolute curvature of the surfaces which is important but rather the difference of curvature, and in order to avoid complicated draughtsmanship, the worm tooth faces have, as a matter of construction, been represented by straight lines, and the whole of the curvature has been assigned to the worm wheel teeth. Thus the tooth sections shown in Figs. 11*a* and 11*b* represent correctly the interspace between the teeth in engagement at various points, and so define the degree of proximate contact between the teeth, but the curvature of the worm and wheel tooth faces respectively must not be taken as individually represented.

Referring to Figs. 10*a* and 10*b*, which are the middle (No. 6) sections respectively of the Lanchester and the D.B.S. gear, it will be noted that whereas the surfaces represented by their development in Figs. 11*a* and 11*b* are surfaces of double curvature in the Lanchester gear, they are ordinary cylindrical surfaces in the case of the parallel worm; clearly, it is necessary to adapt the geometry to the variation of type. Thus, whereas in the Lanchester, as before stated, the development, Fig. 11*a*, must be regarded as to some extent a convention, in the case of the D.B.S. worm it is a true development of a right cylinder, and the assumption of the uniform and parallel worm teeth is strictly accurate. In Figs. 10*a* and 10*b* the three surfaces of section at ¼, ½ and ¾ of the tooth height are numbered respectively 1, 2 and 3 in both cases, and corresponding figures of reference are given in Figs. 11*a* and 11*b*.

In order that it may be quite clear that the difference—the very striking difference—between the character of the clearances in the Lanchester gear 11*a* and the D.B.S. 11*b* are in nowise due to the difference in the manner of defining the surfaces of section, Fig. 11*c* has been prepared on the same basis as that of Fig. 11*a*. It is not only clear here that no exaggeration of clearances has resulted from the method of representation, but it is also clear that the surface of section must necessarily be chosen in harmony with the geometrical basis of design—thus, in Fig. 11*c*, the conventional worm teeth appear in places where they actually do not exist.

Now referring to Figs. 11*a*, *b*, *c*, it may be observed that we are not much nearer being able to define how much of the worm tooth actually takes the pressure reaction, but reading these figures in conjunction with the photographs Figs. 8 and 9, we are in a position to state that for a given size of gear (centres), the effective area called upon to support the load will be greater in one case than in another. With so marked a difference in the curvature of the surfaces between the two types, if there were not some corresponding difference in the test result it would certainly be extraordinary. Yet Mr. H. Kerr-Thomas, in criticising my previous paper, said, referring to the efficiencies of the two types of gear, "moreover, if the subject be treated from a purely theoretical standpoint the two [efficiencies] are equal, and the actual experience of a large number of users who employ a parallel type of worm shows that by this system satisfactory results are daily obtainable." I take no exception to the latter part of this statement—there are degrees of satisfaction—but the suggestion that there is any theoretical sanction for asserting that two so utterly dissimilar types of gear must have equal efficiency is not one to which any reply other than a direct negation is needed.

Of the experimental fact that the Lanchester type of gear will carry more load, centres for centres, than any parallel type hitherto tested, I think there is no doubt whatever. In the results now published there is an adequate explanation of and reason for this experimental fact.

In planning the cutting up of the worm block into sections, consideration was given to the fact that it is desirable to have one of the sections in the plane of the worm axis (as in Figs. 10*a* and 10*b*); the plan adopted is shown diagrammatically in the right-hand section (3) of Fig. 11*c*. The alternative presented itself of either milling away the last section and having no terminal record of the tooth, or of leaving the last section double thickness—the latter was the course adopted. Thus, taking the original face preceding the first section as 0, the total width being 1¼ in., the middle section falls to 6, and what would have been the eleventh section is missing, the terminal face being so numbered.

In the actual cutting of the sections the thickness of the slices and widths of spaces of the different sections was not found to be accurately the same. This was in part due to the fact that the ¼-in. saw used was slightly greedy, and cut the gaps wider and the sections thinner than intended, and in part due to the slices having been further thinned by the process of polishing and etching; in the case of the first set to be dealt with (the Lanchester gear), in which two or three experimental polishings and etchings were tried before the results were satisfactory, this is especially true. In transferring the data to paper in the preparation of Figs. 11*a*, *b*, *c* due allowance has been made for these variations.

The conditions under which the rubbing surfaces of worm and wheel perform their duties are not sufficiently defined to allow an *a priori* estimate of the bearing capacity of the surfaces as based on their radius of curvature, or rather their difference of curvature. The curvature, however, must nevertheless remain some criterion, and, as an approximation to the truth, it would be reasonable to assign the bearing or load capacity on the basis that a certain proximity of contact is effective in the transmission of pressure as due to the oil film. The area of the two surfaces capable of transmitting pressure may be taken as an area over which the tooth surfaces come within some definite small distance one from the other. As a working basis we might take one of the surfaces as a plane, and the area in question will then be proportional, for spherical contact, to the radius of curvature. Where the contact is ellipsoidal and we know the radius of curvature in the major and of the minor axes, the area of proximate contact may be taken as proportional to the product of the square roots of the two.

The application of this method of assessment is not so easy. For example, in the Lanchester gear in Fig. 11*a*, and also in the actual photographs, there are surfaces which are optically in contact, and it would take more refined methods than those so far employed to enable the curvature difference to be assessed. In the D.B.S. gear, on the other hand, the curvature difference, both in Fig. 11*b* and in the photograph, is very considerable, but the variations are very considerable from place to place.*

(To be continued.)

* Over the region by which the tooth load is borne.

* In the parallel type of worm it will be seen from Fig. 11*b* that there is very little constancy in the type of the bearing contact; actual concavities in the teeth frequently make their appearance with no proper driving contact. Beyond this the mere degree of convexity, although a valuable indication, is not the whole criterion in view of the squeegee action dealt with in the discussion of the previous paper. Compare Proceedings 1913–14, vol. vii, p. 279.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

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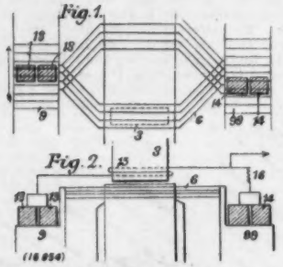
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

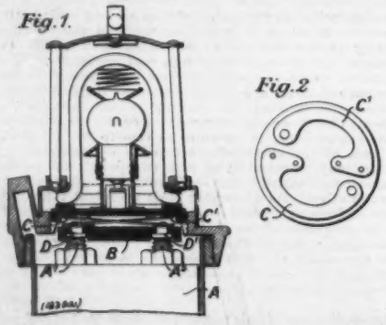
ELECTRICAL APPARATUS.

16,854/15. M. Walker, Manchester. Dynamo-Electric Machines. (4 *Figs.*) November 30, 1915.—This invention relates to dynamo-electric machines of the commutator type having commutating poles or compensating windings. A dynamo-electric machine, in accordance with this invention, is provided with two commutators and has brushes of the same polarity divided into two parts, namely, a forward part and a backward part, distributed on the two commutators, the forward part of the brushes being so connected to the commutating pole winding or apparatus controlling the excitement of the commutating pole that the current collected by the forward



part strengthens the commutating pole, and in so doing tends to equalise the currents collected from the two commutators. The drawings show armature conductors 6, forming an ordinary lap winding. The ends of the conductors at one end of the armature are connected to the commutator 9; the ends of the conductors at the other end of the armature are connected to the commutator 99. The brushes 13 are put on commutator 9, the brushes 14 on commutator 99. The current collected by the forward brushes 13 passes through the winding 15 of the commutating pole 3 and then to the load. The current collected by the backward brushes 14 passes through the resistance 16, and then to the load. (*Accepted November* 15, 1916.)

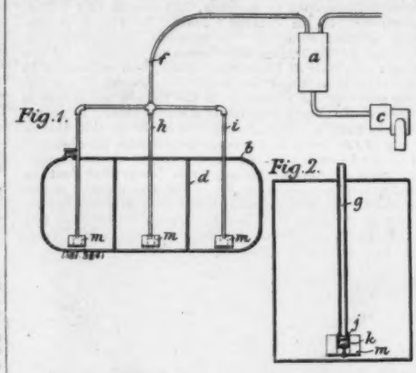
102,001. A. H. Railing and A. E. Angold, London. Electric Hand Lamps. (2 *Figs.*) February 21, 1916.—This invention relates more particularly to miners' electric lamps. The battery is indicated at A, and its solid fixed terminals are shown at A^1, A^2. A switch plate B is provided with two or more springs C, C^1, which are of a half-ring formation. One end of each spring is fixed in the head of the lamp, and the other ends are loosely held to the switch plate B by contact blocks D and D^1 formed in three diameters, the top being the smallest and riveted into the spring, the middle somewhat larger, and



the bottom larger again. Two holes are provided in the switch plate B, into each of which the middle part of a contact block fits easily, and the holes are enlarged underneath the plate to receive the bottom parts of the contact blocks D, D^1, so that they are practically flush with the bottom of the switch plate. The springs C, C^1, are set downwards and force the switch plate B on to the top of the terminals A^1, A^2 of the battery A, and maintain the pressure on both terminals to keep the battery in position at both the "on" and the "off" positions of the switch. (*Accepted November* 15, 1916.)

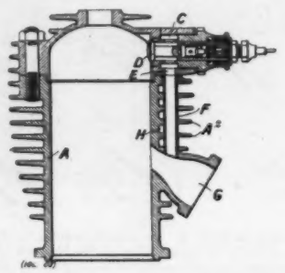
GAS ENGINES, PRODUCERS, HOLDERS, &c.

101,984. J. Higginson and H. Arundel, Stockport. Internal Combustion Engines. (4 *Figs.*) January 5, 1916.—This invention relates to liquid fuel supply arrangements of internal combustion engines, and particularly to arrangements of the type in which the fuel is fed to the engine by a combined vacuum or suction and gravity action. *a* is an intermediate vessel placed between the main fuel tank *b* and the carburettor *c*, the intermediate vessel drawing fuel by suction from the main tank and feeding same by gravity to the carburettor. The applicants divide the main fuel tank by division plates *d* into a plurality of compartments, which may intercommunicate at their upper ends. The tank *b* is provided with an air vent, and the supply conduit *f* between the tank and the intermediate vessel is supplied with a plurality of branches *g*, *h*, *i*, one extending into each compartment. The open lower end of each branch has a



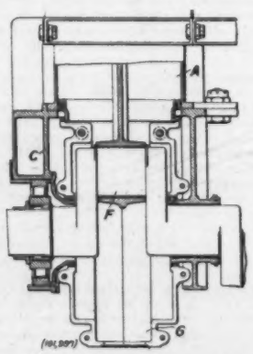
valve fitting *j* thereon with which co-operates a valve *k* controlled by the float *m*. The valve is adapted, when its compartment is nearly empty, to close the branch pipe connection so as to isolate the source of suction from said compartment. (*Accepted November* 15, 1916.)

102,002. The Villiers Engineering Company, Limited, Wolverhampton, and G. Funck, Coventry. Internal Combustion Engines. (1 *Fig.*) February 23, 1916.—The invention relates to two-stroke cycle internal combustion engines. The cylinder A is provided with a detachable head in which is the chamber C containing the compression release valve D. The underside of this chamber is provided with a hole E, which registers with



the upper end of a pipe F, which is separate from the cylinder and fits into holes in the fins A^2. This pipe discharges into the exhaust passage, G. It is preferred that the pipe be spaced a certain distance from the cylinder wall so that there is a complete air passage H right round it. By using a detachable head to the cylinder A the forming of the passage into which the pipe F fits and the fitting of the latter is a simple matter. (*Accepted November* 15, 1916.)

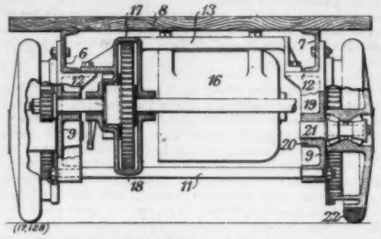
101,997. A. Craig, Coventry. Internal Combustion Engines. (2 *Figs.*) February 16, 1916.—This invention relates to internal combustion engines of the kind in which the crankshaft is supported by hangers from the cylinder element. According to this invention, there is provided in the plane of each



crank pin F a crank chamber G, which is supported partially or wholly from the adjacent cylinder A. The crank chambers are therefore all separate from one another and any one can be easily removed. Each crank chamber may be attached at each side to the adjacent hanger C, or makes an oil-tight joint therewith. (*Accepted November* 15, 1916.)

LIFTING AND HAULING APPLIANCES.

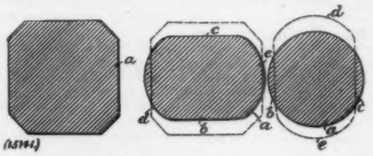
17,128/15. The British Thomson-Houston Company, Limited, London. (*General Electric Company, Schenectady U.S.A.*) **Warehouse Tracks.** (5 *Figs.*) December 6, 1915.—6 and 7 indicate channel beams forming the side frames of the truck, upon which rests the goods-carrying platform 8. Carried by and acting as a support for each channel beam is a pedestal support 9; 11 is a tie rod which holds the lower ends of two opposite pedestals rigidly together. Each pedestal has a flat ledge 12 adjacent its upper end upon which rests the ends of a bridge member, 13. This bridge member has attached to it the casing of a motor 16, for which it forms the support. Carried by this bridge member, and preferably formed integral therewith, is the upper half 17 of a gear casing, the lower half of which is indicated at 18. It will be seen that the bridge member not



only supports the motor, but also forms a brace and tie rod between the side beams of the truck. Each pedestal has strengthening flanges 19 and a boss 20 in which is fastened a stub axle 21 for a running wheel 22. (*Accepted November* 15, 1916.)

MINING, METALLURGY, AND METAL WORKING.

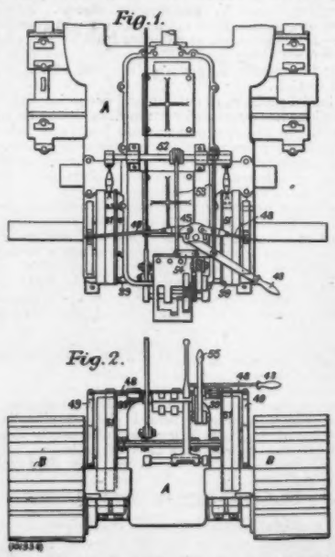
15,141/15. Samuel Fox and Co., Limited, C. Thickett and W. Hawksworth, Sheffield. Rolling Mills. (6 *Figs.*) October 26, 1915.—According to this invention, the bar *a*, which may have an initial shape such as is shown in the left-hand figure, is passed through the rolls of a rolling mill so that in the early stages it is made to assume a shape such as is shown in the



central figure, wherein the two sides *b*, *c*, of the bar are rectilinear and the other two sides *d*, *e* are curved, the rolls being formed to produce such section. The bar is then turned upon one of its curved sides, and, passing through a guide which contacts with the rectilinear faces *b*, *c*, is passed through the later stages of the rolls so that it assumes finally the round form shown in the right-hand figure. (*Accepted November* 1, 1916.)

MOTOR ROAD VEHICLES.

101,954. Caterpillar Tractors, Limited, London. (*The Hilt Manufacturing Company, Stockton, Cal., U.S.A.*) **Traction Engines.** (3 *Figs.*) November 26, 1915.—This invention has reference to traction engines of the chain-track type, in which the whole of the weight of the machine is supported upon a pair of endless tracks, and the vehicle is steered by varying the relative speed of such tracks. A represents the frame of the tractor and B, B the two endless chain tracks, one on each side of the tractor. The steering lever 43, which controls the two steering clutches, carries a crank member 45, having two segmental slots to accommodate corresponding pins on links 48, said links 48 connecting to levers 49, each fulcrumed on one side of the machine in juxtaposition to one of the clutches. The levers 49 are each adapted to move a friction clutch member for the purpose of engaging or disengaging one or the other of two steering friction clutches. Brake mechanism is provided for



the other clutch members 39 in the form of a friction band 51 for each, which bands are operated by a separate rocking shaft 52 actuated by links connected to an equalising bar 54. This bar 54 can be operated by a hand lever 55 by means of a plate to which the rocking bar 54 is pivoted. Each link 53 has a lug formed thereon in position to be engaged by a tooth on the slotted crank 45. When the latter is moved to disengage the clutch mechanism at either side, a continued movement of the slotted crank 45 will engage one of its teeth with the appropriate lug 57 and act to apply the brake mechanism on the particular steering clutch which has been disconnected. The turning or steering movement may be accentuated by applying one or the other of the band brakes 51 to the drum on the corresponding clutch member 39, which is done by continuing and increasing the movement of the lever 43. (*Accepted November* 8, 1916.)